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★ *The Magazine for Engineering Designers*

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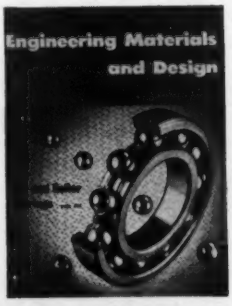

COVER—A single-row radial ball bearing by Ransome & Marles Bearing Co., one of the many types discussed in the article that starts on page 562.

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W45

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Materials—the Key to Fuel Cell Development

IT IS MANY YEARS since a new principle in electro-chemistry was evolved, but the recent developments on fuel cells in the U.S.A., Russia and in Great Britain are largely the result of materials research, which has provided the electro-chemist with new alloys, plastics and other special substances to enable old ideas to be developed on a practical basis. The hydrogen-oxygen cell, now being developed by Mr. F. T. Bacon under the sponsorship of the National Research Development Corporation, was first envisaged in 1839 by Sir William Grove. The cell has only become a practicable possibility by virtue of the improved techniques for producing sintered nickel electrodes with a highly controlled porosity and also a clever treatment of the oxygen electrode with lithium, followed by a pre-oxidation, to make it withstand caustic potash at temperatures around 200 deg. C. The success of the cell is also dependent on the production of a gasket material which must withstand very severe corrosive conditions coupled with high temperatures and pressures.

Considerable activity is reported in the field of high-temperature cells using hydrocarbon gases as basic fuel, and in these cases the electrolyte is usually molten salts or oxides. The cells operate at about 600 deg. C., but usually at atmospheric pressure. As with the Bacon cell, the high temperature of operation is a serious disadvantage for small-scale units and will probably prevent the use of fuel cells for consumer applications such as motor cars. Another project being studied in the U.S.A. is the use of carbon electrodes which allow cells to be operated at room temperature and pressure. Even if the high current outputs of the Bacon cell cannot be achieved in this way, there are still many useful applications for such a cell, but the whole success of the research depends on the production of a suitably active carbon which is not easily poisoned. In spite of the tremendous expenditure now taking place in many parts of the world, it is not expected that a sound, practical fuel cell will be marketed for at least five years, for there are still many material problems to be overcome.

Progress in Diffusion Techniques

METAL DIFFUSION PROCESSES are used to impart to ordinary steels a surface which is resistant to heat, wear or corrosion which could otherwise only be obtained by the use of expensive alloy steels. The majority of commercial applications so far developed employ chromium or aluminium for this purpose, but recent experiments have shown that other metals such as nobium, tantalum, molybdenum, vanadium and beryllium are equally practicable.

Work of the Fulmer Research Institute has shown that surface treatments offer scope for the future development of materials for use at high temperature in cases where present application is restricted by poor oxidation resistance. For instance, in molybdenum steels full use might be made of their good creep properties by suitable surface protection. By this means it may be possible to extend the use of ferritic steels at temperatures up to 650 deg. C. and make them competitive with more expensive austenitic steels, provided that the heat treatment involved in the surface coating does not seriously reduce their properties at elevated temperatures.

The Dicrom process operated by Metal Diffusions Ltd. is claimed to be a considerable advance over previous methods, principally because of the high purity of the chromium surface. With earlier processes, surface purities of over 50 per cent were almost impossible, but with the new process surface purity values up to 96 per cent are said to be obtained. These superior surfaces enable mild steel to be used at temperatures up to 1,180 deg. C. with the same oxidation resistance as a 40/22 nickel-chromium alloy steel, and at much reduced cost. A combined chromium/aluminium diffusion is said to give effective corrosion resistance up to 1,300 deg. C. The higher purity of the new treated surface is said to permit fuller use to be made of the physical properties of chromium, i.e., its extreme hardness, its resistance to abrasion, its immunity from attack by many chemicals and its low coefficient of friction.

Impact Compaction of Powder Metals

THIS METHOD is without commercial precedent in the powder and metal field, but has been used for the compaction of very dense refractory ceramic shapes. The compaction of the metal powders is produced by a series of impacts which are made to occur at a high cyclic rate, the high frequency of the impacts producing two effects: one a vibratory effect and the other a forging effect. The vibratory action improves the flow of the metal powder to all parts of the die and hastens the expulsion of entrained air. The forging effect is brought about by the high-energy impacts which densify the powders into a homogeneous mass and produce a high-density "green" compact.

The improvement in flow resulting from this method increases the prospect of producing parts with more intricate shapes and with larger cross-sectional areas than are possible by conventional means.

In conventional presses the compacting force is steadily applied by means of a heavy ram and held for a short period of time. Since for dense compacts the applied pressure may be as high as 50-100 t.s.i., the machine must be of heavy and powerful construction in order to produce the required loads, and to absorb the structural and bearing reactions. With high-cyclic-rate impact compaction, on the other hand, the energy is delivered to the work by a lightweight high-velocity hammer being brought suddenly to rest by the work itself or by an intermediate member, thereby transferring the high energy of the moving hammer to the work.

In the impact compaction process the blows are delivered in rapid succession (1,000-2,000 blows per minute) and, as a consequence of the rapidly repeated blows, a very effective job of driving the entrained air out of the powder is accomplished.

Shapes difficult to make by conventional pressing, such as those with undercuts, re-entrant angles, threads and deep curves, may be formable by the new process because of the improved flow and uniform pressure distribution.

Current powder metal practice requires that metal powders be selected on the basis of flow and compaction ratios as well as upon the response to sintering and the mechanical properties of the finished part. By means of the high-cyclic-rate impact compaction process, the flow and compaction ratio factors can become less important.

Studies by the Armour Research Foundation are intended to stimulate serious consideration of high-cyclic-rate impact compaction and to obtain support for the development of method and prototype equipment.

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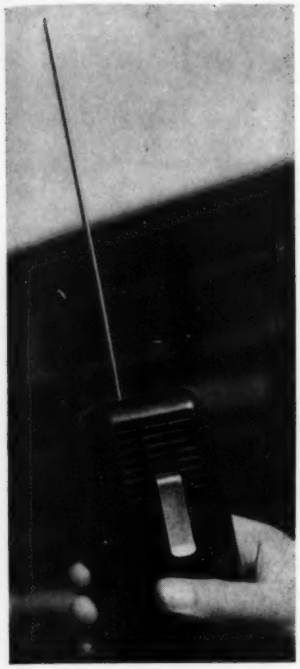
PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN



MINIATURE TRANSCEIVER

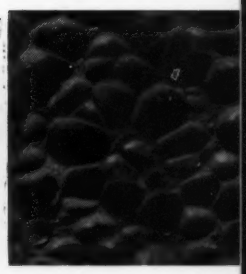
For exchanging messages within an airfield or industrial premises, W.S. Electronics Ltd. have produced a 15-oz. battery-operated transceiver which slips easily into a breast pocket. A controlled radiation loop system (to give military security) operates in conjunction with an L.H./U.H.F. control station which can call up to fourteen outstations individually or simultaneously.

PLASTICS BODY ON SPORTS CAR

Latest use of reinforced plastics in the motor industry is in the TVR Grantura, made by Layton Sports Cars Ltd. Bakelite polyester resin, with glass fibre, is used throughout for bodywork, flooring and many components. Powered by either a Coventry Climax 1,220-cc. engine or a Ford 100E engine, it has independent front and rear suspension, and a tubular chassis.

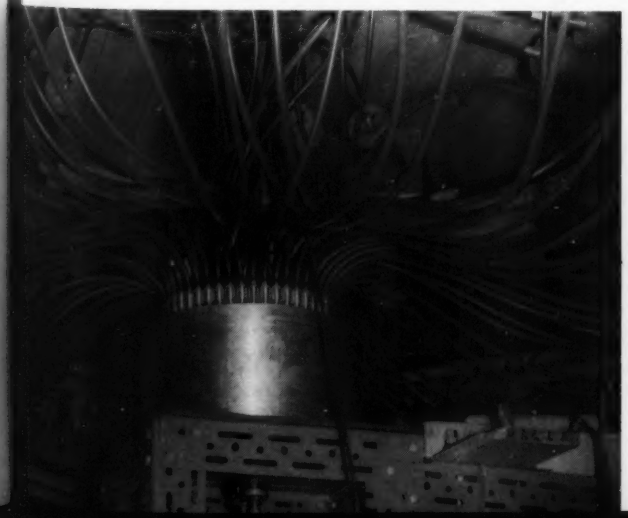
LOW-TEMPERATURE INSULATION

To insulate this liquid-methane unloading line at Canvey Island, which operates at —160 deg.C., the 10-in. dia. aluminium pipe was insulated with Onazote. It was applied in three 2-in. thick layers, with joints staggered and sealed with polyethylene tape on the second layer and Denso tape on the outside layer. (Picture far right shows microcellular structure of Onazote.)



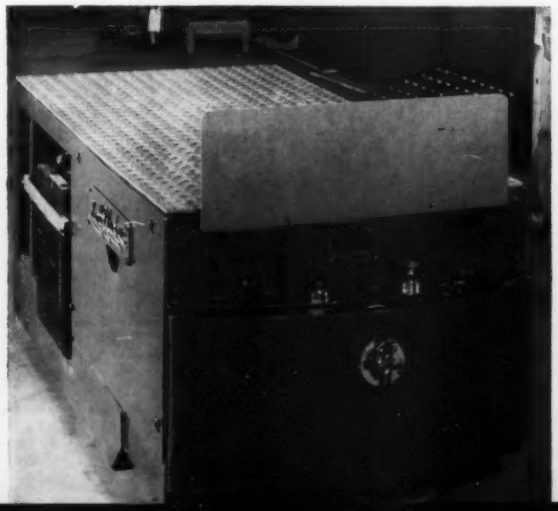
HIGH-CURRENT SWITCH

A 2 million ampere discharge can be handled by this high-current switch developed by Hawker Siddeley Nuclear Power Co. for the U.K.A.E.A. Produced for controlled thermonuclear reaction projects, the switch is being tested and developed on a 30,000-volt condenser impulse generator and, on initiation, the peak current is reached in less than one-millionth of a second.



DRIVERLESS TROLLEY

This is the Robotug that operates by following a single wire laid just below ground level, through which an alternating current of specified frequency is passed. Forty of these trolleys, developed by E.M.I. Electronics Ltd., have recently been ordered for use in a Midlands factory, and British Railways western region already have them in service at Newton Abbot.



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Yttrium Under Investigation

IT HAS PREVIOUSLY been thought that yttrium was too brittle for most engineering applications, but work by the U.S. Bureau of Mines has shown that removal of dissolved oxygen enables the metal to be produced in a ductile form. This is an important announcement and may lead to interesting applications, such as in nuclear engineering, where the low neutron absorption and high melting point (approx. 1,250 deg. C.) are attractive features.

In Russia, yttrium is regarded as a very promising alloying component when added to metal alloys. It exerts a de-oxidising and modifying effect on all types of alloys, and in a number of cases (e.g., magnesium and aluminium alloys) it has been found to give increased strength. Introduction of small quantities (0·1-0·2 per cent) of yttrium reduces the size of the grains of almost all cast metals studied (chromium, titanium, zirconium, molybdenum, etc.).

In the field of magnetic materials the Kearfott Co. Inc. have issued data on a polycrystalline ytttrium-iron garnet which is being examined for various uses in non-linear electronic devices. Although at present little is known about the range of applications for this material, it has been found particularly useful as a replacement for ferrites in such devices as parametric amplifiers and phase shifters. Since the line width of this material is very narrow, applications demanding narrow band operation in the 10-kMc/s frequency region may find it excellent. Further, since the lower limit of operational frequency depends on line width, low-frequency operation at about 1 kMc/s and below is possible.

Grid Method in Stress Analysis

THE GRID METHOD of experimental stress analysis is one of the simplest and oldest of experimental methods used in determining stresses. However, no known attempt has been made previously to employ the grid method in a dynamic stress analysis.

A recent paper in the *Journal of Applied Mechanics* introduced the dynamic grid method and its application to two examples. The static application consists essentially of the following:

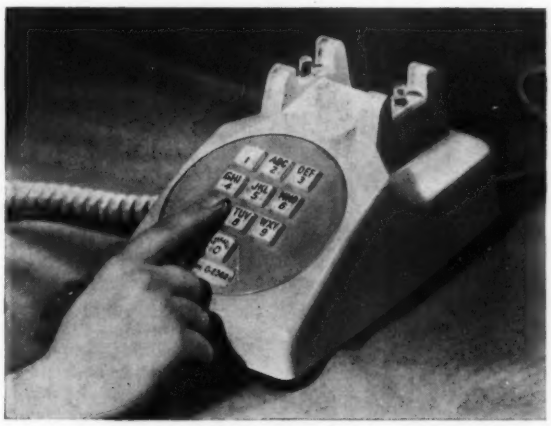
1. A network of lines (rubber threads) is embedded in a transparent model material.
2. A no-load photograph is taken of the model to record the undeformed state of the grid.
3. A photograph is taken under load to record the deformed state of the grid.
4. The grid-line positions are measured on both load and no-load photographs (to within $\pm 0{\cdot}0003$ in.).
5. Differences are made between the two sets of measurements to obtain the displacement fields.
6. The displacement fields are differentiated to obtain the strain fields.
7. The strain fields are converted to stress fields by using Hooke's Law and suitable values for the elastic constants E (modulus of elasticity) and ν (Poisson's ratio).

The dynamic grid method differs from the static grid method only in steps (3) and (7). In the dynamic case, a photograph is taken over a very short interval of time, i.e., short exposure time, and at a number of different times after the application of the time-dependent load. Also, the variations in the elastic constants E and ν with the rate of load application must be taken into consideration in converting the strain field to the stress field.

In this investigation a low-modulus model material (urethane rubber) was employed, since this material has two advantages: (a) the stresses propagate in the material relatively slowly (about 300 f.p.s.); hence the exposure times which are of the order of 2 microsec. were, for all practical purposes, instantaneous.

(b) The material exhibits relatively large displacements under small loads, which is advantageous, since a strain level of at least 1 per cent is necessary for accurate displacement determinations.

The grid method and the photo-elastic method were used together with a microflash light source to record grid distortions and photo-elastic fringe patterns in a model subjected to dynamic-loading conditions. By considering a strut subjected to axial impact, it was possible to establish that the static and dynamic values of Poisson's ratio were identical, and the strain-fringe value of the material varied with strain rate. In addition, stresses in the axial and transverse directions were determined along the centre line of the strut. Finally, the methods established were applied to the problem of a circular disc subjected to diametrical impact and both principal stresses were determined along a vertical diameter at one instant during impact.



A further use for the transistor—this time making possible the bush-button telephone.

Push-button Telephone

A PUSH-BUTTON TELEPHONE DEVICE that may eventually replace the rotary type of dial is being developed at the Bell Telephone Laboratories.

Push-button calling has been made feasible by modern electronic advances, such as the transistor, applied in an extensive development programme. At the same time, the appearance and operation of the push-button telephone have, so far as possible, been tailored to suit people's preferences and capabilities, as revealed in laboratory tests.

To place a call on a push-button telephone, the user simply presses buttons instead of turning a fingerwheel. As each button is pressed, two simultaneous musical tones are generated and transmitted to the exchange.

The present switching system employed in telephone exchanges would not respond to these signals, but the greater speed and convenience of the push-button system has led to the development of a translator which is partly mechanical and partly electronic. This equipment would enable the new push-button instruments to be used with existing exchanges.

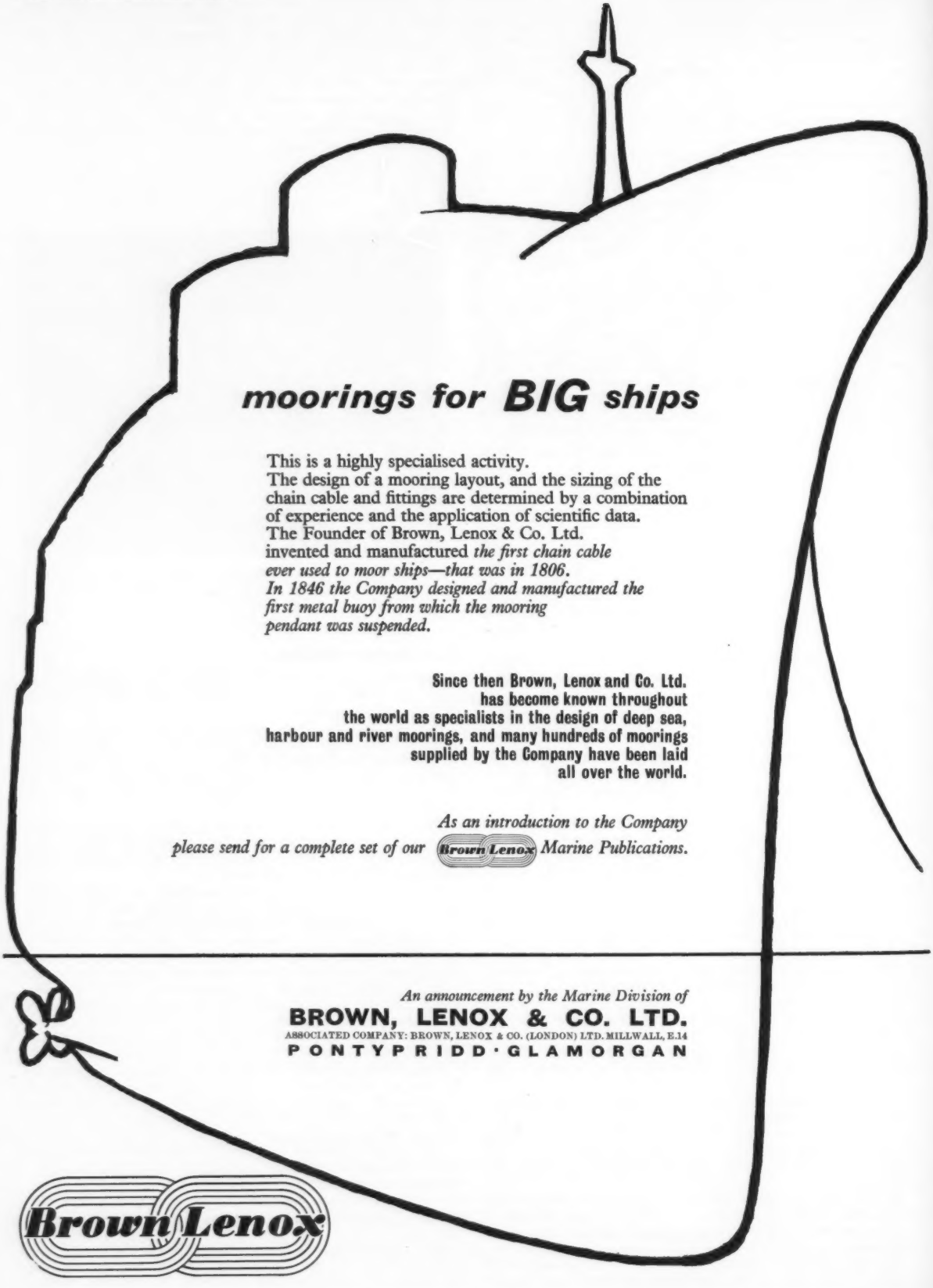
Simultaneously, research has been undertaken to discover which kind of push-button set people would like most and could use most rapidly and accurately, and hundreds of persons have helped engineers at the laboratories find out which button arrangements, size and "feel" might be best.

A push-button mechanism has been efficiently designed to fit into the same shell that now houses the standard instrument, simply replacing the rotary dial so that no extra apparatus is needed by the ordinary subscriber at his end of the new switching system.

The manual operation of signalling with push-buttons takes only a fraction of the time needed for present dialling. The average time for tapping out a seven-digit number is about five seconds, although some persons can do it in less than two seconds. Rotary dialling, by contrast, takes an average of nine seconds.

It is understood that British Post Office engineers are actively investigating the push-button system, but no decision has yet been taken regarding its serious development in this country.

EMD 1651 for further information



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Plastics Impregnation of Iron Powder Parts

THE APPLICATION of powder metallurgy for the manufacture of important structural parts has made rapid strides in recent years. This is especially true of iron powder parts, since new pressing and heat-treating techniques allow the production of larger and high-strength components and components with special "tailored" properties.

Many of these iron powder parts must, however, meet requirements for corrosion resistance and pressure tightness. Resistance to corrosion can be met by a suitable electroplated coating, which, to be effective, must be free from porosity, a factor also necessary for pressure tightness.

Elimination of porosity in metal powder parts poses complex problems, because of the non-uniform porosity caused by slight variations in pressure, amount of powder fill and direction of pressing. Even prior to the development of the "newer" powder metallurgy fabricating methods, impregnation of iron powder parts (usually for plating) was difficult. Parts that have been in contact with oil as a result of quenching cannot be properly impregnated, even when cleaning techniques such as ultrasonic vapour degreasing are used. Parts that are re-pressed to a high density do not lend themselves to proper impregnation. The same is true of parts that are coined or "sized". Preforming and briquetting procedures also affect the impregnation process.

Using a special technique, engineers of the American Metaseal Corp. claim to have solved the problem of impregnating iron powder parts which must be heat-treated to increase their strength and hardness, by applying a solution *prior* to the heat-treating operation. This new technique involves impregnating the parts with polyester impregnant, which is then converted to a carbonised residue by a "burning-out" process. The parts are then subjected to normal heat-treatment. The residue remains in the pores, and acts in the same manner as the conventional polyester impregnant to prevent salt entrapment during electroplating.

Brittle Materials Forged

BRITTLENESS—or at least non-ductility—is a feature of many new high-temperature metals and alloys as well as a known feature of glasses and ceramics. Applications of these materials are therefore often limited by the difficulty of producing parts economically. A recent Soviet report on a process known as back-pressure forging may, if it is true, lead to important developments in forging non-ductile materials. No details of the process have yet been publicised, but it consists of subjecting a billet to very high compressive stresses from all directions before and during the forging operation. It is claimed that brittle materials such as marble can be forged in this way without cracking or tearing. If this new process is successful, it may open up useful applications for materials which cannot now be produced in complex shapes.

This motor was developed by B.T-H. for the Parnall-Yate Ten-Ten cleaner.

New-type Motor

A NEW high-speed universal motor has recently been developed by Associated Electrical Industries Ltd. for use in the Parnall Yate high suction cleaner, the Ten Ten.

The motor, known as type BB.1306-B, has a nominal rating of ½ h.p. and the armature rotates at over 20,000 r.p.m. and creates a suction of over 60 in. of water when the inlet to the impellers is sealed.

The motor is of the type usually fitted within cylindrical vacuum cleaners and incorporates a two-stage impeller unit. The construction of the motor comprises two die-cast aluminium endshields spigoted on to a rigid laminated stator core. A ball bearing supports the rotor at the impeller end and a self-aligning porous bronze sleeve bearing surrounded by a large oil reservoir is used at the commutator end. The brush-holders consist of nylon mouldings designed to produce extensive creepage distances to eliminate tracking under dirty conditions.

They are built on a new production line incorporating modern automatic machines of many types, and great care has to be exercised in all stages of manufacture to ensure an efficient and quiet motor.

IN NEXT MONTH'S ISSUE . . .

Principle features planned for the December issue of ENGINEERING MATERIALS AND DESIGN include:

Photoelasticity Can Help the Designer
Advantages of this method of experimental stress analysis.

Fire-resistant Materials
Behaviour and trends of fire insulation materials.

Materials Research for the Royal Navy
Roles of the Admiralty Materials Laboratory and Central Dockyard Laboratory.

Uncommon Engineering Materials
Lesser-known materials for special environments.

Survey of Heating Elements
Study of the types available and their correct application.

Bonded Metals for Heat Transfer

THE ANNOUNCEMENT of many new, exciting composite materials is liable to eclipse the progress of older but nevertheless important processes which have been making steady headway. Al-Fin molecular bonding, first introduced in the U.S.A. in 1941, is a patented casting process whereby aluminium and magnesium alloys can be metallurgically bonded to a wide range of metals including cast iron, carbon and alloy steels, stainless steel, nickel, Inconel, the Nimonics, titanium and the special controlled expansion alloys. In this way the corrosion resistance, wear properties or high strength of the heavy metals can be combined with the light weight and good heat conductivity of the aluminium or magnesium. Although now well known for its applications to engine cylinders and brake drums, the Al-Fin process is finding applications in a very wide range of engineering products such as compressors, alternators, pistons and guided missiles. In most of these applications there are problems of heat transfer combined with some specific condition such as the necessity for good wear resistance or magnetic properties. The bond is said to be superior to any mechanical joining, permitting excellent heat transfer across the joint and freedom from electrolytic corrosion. Wellworthy Ltd. are the head licensees in the U.K. for this process.

Top attraction at the Farnborough Air Show this year was the S.R.N.1 Hovercraft, built by Saunders-Roe Ltd. for the National Research Development Corporation.

Looking Back at Farnborough

AN ENGINEER visiting the Farnborough Exhibition this year cannot have failed to notice two outstanding trends: the dominance of electronics and the emphasis on high-temperature materials. Apart from the actual flying and control of aircraft, electronic engineering is now essential for the design, construction and testing of modern aircraft and many of the components used in them. Designers in some of the older engineering industries are sometimes slow to appreciate the tremendous service which electronics can give them, and it is worth their while examining particularly how a computer is able to save months of work on a drawing board by simulating the performance of a product before even a test model has been made. The wonderful reliability of modern electronic equipment used in aircraft should also raise the confidence of engineers who have in the past doubted whether it could be trusted not to fail when incorporated with traditional engineering products.

In the field of high-temperature materials both metals and plastics showed some interesting developments, and in some cases combinations of both have proved very successful. Among the most interesting developments are flexible hoses said to be satisfactory from −70 to +230 deg. C., equipment wires for continuous operation up to 250 deg. C. and transformers to work at 500 deg. C. There is no doubt that the impetus given to the development of new materials for aircraft applications will benefit many other branches of engineering. In rubber technology the rapid growth of silicone rubber components has been due in no small measure to the requirements of the aircraft industry. The ability of silicones to withstand wide extremes of temperature (of the order of −60 to +200 deg. C.) with little change in their physical or dielectric properties is of great significance for many non-aircraft applications. Some of the newer rubbers, such at nitrile rubber, are offered for use at temperatures up to 160 deg. C. and fluorinated polymers are claimed to be satisfactory up to over 300 deg. C. The demands of the aircraft industry are continually outstripping the results of research and there is now talk of extending the temperature range of rubbers up to over 500 deg. C.

A new trend is the vacuum melting and casting of metals. This has now passed out of the research stage and is on a production basis with at least three manufacturers. Among the advantages of vacuum casting are superior mechanical properties, improved surface finish, higher definition and increased yield. Vacuum melting has enabled some of the special high-strength alloys to be made with improved hot-working characteristics and promises to permit the production of some of the normally brittle metals in a more ductile form.

The examples quoted are only a few of the many important developments which have resulted from the activities of a virile industry. With the slowing down in aircraft production, many firms are looking for new applications and outlets for their products, so that engineers in other industries should find suppliers only too willing to co-operate in new ventures. It should also be realised that, but for the pioneering efforts of the aircraft industry, many of the new materials would never have appeared, at least in a practical and economic form. It is also very noticeable how many of the larger aircraft companies are putting their engineering experience to use in other fields such as cars, computers, instruments, plastics, agricultural machinery and nuclear projects. They are tackling these new products with the energy and enthusiasm we have come to expect from them, and this may well provide a stimulus to engineering design as a whole, an activity which many people have said is long overdue.

Wire Tyre without Inflation

A NEW KIND OF TYRE that contains neither rubber, fabric nor air has been developed as a result of space flight needs in the U.S.A. Built by the Goodyear Tire & Rubber Co., it can withstand extremely high temperatures, and is constructed entirely of wire, rather similar to a wire wheel used in home workshops. It is designed for use as a landing wheel and tyre for vehicles which pass through the thermal barrier on their re-entry into the air mass, as will be necessary in most space ventures. It will withstand temperatures in 500-1,100 deg. C. range in flight and during landings in conditions which would melt rubber tyres.

Although made of wire, the tyre has load-deflection characteristics very similar to that of pneumatic tyres. It also has a higher rolling resistance, which provides an advantage in braking and slowing down the aircraft. It has already been tested on a dynamometer which simulated landings at different speeds and with various loads.

Weight of the wire tyre and wheel (which is 14 in. in diameter and 4 in. wide) is about 40 lb. It can be made of various alloys, depending upon the application.

Some of the advantages the wire construction offers over the simple skid pad are better absorption of runway irregularities and landing impact, greater total contact area, better scavenging action because of wheel rotations, better cooling of the pad surface and higher directional stability.

Ship Hydrodynamics Laboratory

IN NO FIELD of engineering does the building and testing of models play a more important part than in ship design and, although it is nearly a hundred years since models were first used to determine the best shape of hull, much still remains to be learnt about interpreting results of model tests. The use of models introduces scale effect problems which are now being studied by the use of larger hull models at the new N.P.L. ship hydrodynamics laboratory at Feltham.

A new towing tank 1,300 ft. long and 25 ft. deep has recently been built for this work. It is nearly twice as long as the largest existing tank at Teddington and it will also enable models to be tested at the increased speeds required from modern ships. There is a growing need for more knowledge on the behaviour at high speeds of hydrofoil sections, suitable for use in marine propellers, both to learn how to avoid or delay cavitation and also to live with it. This will be of value, not only for propeller design but also for such things as hydrofoil craft, shaft appendages and stabilising fins.

Other facilities at the new laboratories are a water tunnel (the hydraulic equivalent of a wind tunnel) having a maximum water velocity of 50 ft./sec. (approx 34 m.p.h.) and a 100-ft. square sea-keeping tank, where models under remote control can be run on courses at all angles to artificial waves.

FOR MORE INFORMATION:

Society of British Aircraft Constructors, 29 King Street, London, S.W.1.
Fulmer Research Institute Ltd., Stoke Poges, Bucks.
Metal Diffusion Ltd., Worton Works, 292 Worton Road, Isleworth, Middlesex.
Kearfott Co. Inc., 1500 Main Avenue, Clifton, N.J., U.S.A.
Wellworthy Ltd., Lymington, Hants.
Associated Electrical Industries Ltd., Rugby.
Bell Telephone Laboratories, 463 West Street, New York, 14, N.Y.
American Metaseal Corp., 607 65th Street West, New York, N.Y.
Journal of Applied Mechanics. "Developments in the Application of the Grid Method to Dynamic Problems." By Burelli, Dally and Riley. Paper No. 59-APMW-1.
Armour Research Foundation, Technology Center, Chicago, 16, Ill.
Goodyear Tire & Rubber Co., Akron, Ohio, U.S.A.
National Research Development Corporation, 1 Tilney Street, London, W.1.
Ship Division, National Physical Laboratory, Teddington, Middlesex.

PSYCHOLOGY IN DESIGN

ERGONOMICS has been ridiculed by some engineers as an attempt by the scientist to gate-crash into practical engineering, but whether we use this word, or the American phrase "human engineering", there is little doubt that the science of man in relation to machines is a subject which designers must try to understand.

Ergonomics as applied to engineering goes far beyond the simple placing of levers within reach or the siting of instruments for convenience of the operator, although even these fairly obvious design points are frequently neglected, but it embraces the whole aspect of human behaviour with technical equipment. It is not possible to explain the factors which control it in mathematical or physical terms and, realising this, E.M.I. Electronics Ltd. appointed a research psychologist, Mr. B. Shackel, to advise their designers in these matters. This was five years ago, and until very recently we have not heard of any other companies being far-sighted enough to take a similar step. Now we hear that Smiths Aircraft Instruments Ltd. have appointed Dr. Norman Loveless, a lecturer in psychology at Dundee, as consultant in ergonomics as applied to aircraft instrumentation.

What strikes us as remarkable is that it is taking so long for industry to recognise the importance of ergonomics in engineering design. Even with vital instruments such as altimeters, it was realised ten years ago that pilot errors in reading these instruments were commonplace, but it was not until February this year that a committee was set up under the Ministry of Transport and Civil Aviation to investigate the design of aircraft altimeter faces and mechanisms.

We have previously referred to the need to reconsider the training of engineering designers from the point of view of materials and in appearance design. Now we ask that the already overcrowded syllabus should include ergonomics, for we believe that only by including this subject in the initial training of designers will the products of the British engineering industries be considered really up to date. This is important not only from the point of view of sales, but is closely related to safety and convenience, both of which are receiving increasing attention from managements, unions and governments. There will no doubt be objections raised to adding another subject to the already long list for designers to study, but we feel that such a course would result in not so much the cramming of a multitude of facts, but the adoption of a particular attitude of mind.

After all, many design faults which are pointed out by the psychologist may be caused by what is called lack of common sense; but, nevertheless, they could not have been so obvious before attention was drawn to them, otherwise the designer would have spotted them himself.

It will take a long time to develop a new generation of designers who appreciate these matters and in the meantime progressive companies could do worse than to follow the examples of Smiths and E.M.I. by appointing specialists to advise them.

The Editor

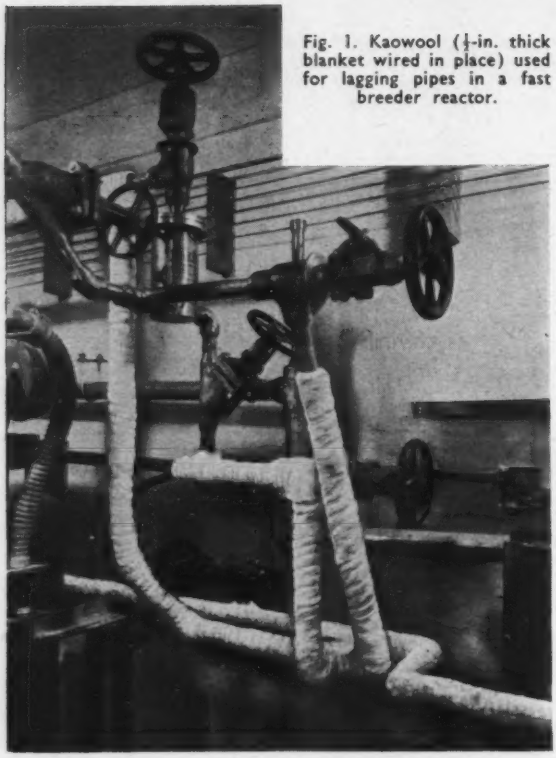

Fig. 1. Kaowool (½-in. thick blanket wired in place) used for lagging pipes in a fast breeder reactor.

REFRACTORY FIBRES USED IN MODERN INDUSTRY

Wherever high temperatures are involved—from nuclear engineering to more conventional domestic furnaces—aluminium-silicate fibres are being widely applied as refractories. The principal types and their properties are discussed here

by C. Z. CARROLL-PORCZYNSKI*

THE demands of atomic energy, commercial jet transport and modern military weapons for extremely high-temperature insulations cannot be met by the normal soda-lime-silica or even boro-silicate types of glasses. For such purposes, a number of important fibrous refractory materials have been recently developed which are capable of maintaining their original properties on prolonged exposure to temperatures in the range of 540-1,100 deg. C., and for short periods even to 1,650 deg. C.

One of the most significant groups in this field consists of the aluminium-silicate fibres which have been developed in the U.S.A. by the Carborundum Co. (under the name of Fiberfrax) and the Babcock & Wilcox Co. (with the name of Kaowool).

FIBERFRAX

This is one of the most successful refractory fibres at present available. Besides possessing many unique properties, it is also one of the cheapest industrial materials. It has been known for some time that refractory mineral wools can be produced by fibrising fused natural minerals of an alumina-silica composition, e.g., kaolin, bauxite and kyanite, and that refractoriness of the resulting wool is imparted by the relatively high ratio of alumina to silica.

It has been found that refractory glass compositions in suitable fibrous form can be obtained by melting and fibrising mixtures of alumina and silica containing a small amount of modifying agent such as borax glass. An example of such a composition is:

White alumina ore (98·9 per cent alumina)	50 parts by weight
Flint	50 parts by weight
Borax glass (sodium borate) ...	1·5 parts by weight

This, after thorough mixing, is fused in a special type of arc furnace until a substantial batch of molten material is obtained. The furnace is then tilted to allow the molten material to pour from the furnace in the form of a small stream, which is struck at approximately right angles by a stream of compressed air at a pressure of 80 p.s.i. The stream of molten material is dissipated in the form of fine fibrous glass, collected upon a ¼-in. mesh screen about 5 ft. from the front of the furnace. The resulting fibrous glass, after the removal of any pelletised material, is ready for fabrication into batts or packaging in loose form.[1, 2]

Recently a process has been developed for the refining of aluminium-silicate fibres, by which a substantial proportion of unfibrised particles is removed from the material. Such purified fibres are particularly useful for the manufacture of inorganic fibre papers.[3]

It has been reported[4] that Fiberfrax does not lose resiliency at temperatures as high as 1,250 deg. C., and that the fibres are opaque to infra-red radiation, which is a factor of increasing importance at temperatures over 500 deg. C.

Applications

BULK FIBRES—The main outlet for Fiberfrax loose fibres is in the high-temperature insulation field, such as loose insulating fill for roofs of furnaces, tunnel kilns and muffles. Bulk fibres are also said to provide an excellent thermal barrier in walls of furnaces employed for brazing purposes, sulphur burning, etc. Loose fibres also find extensive use as a packing in furnace joints, for cracks in fire boxes, in boiler expansion joints and other similar applications where the retention of resiliency of a fibrous material on prolonged exposure to high temperatures is particularly desirable. Short aluminium-silicate fibres can

* *Manager, asbestos division of Metal Traders Ltd.*

TABLE 1. General properties of Fiberfrax fibres

	Short Staple	Long Staple
Composition, %		
alumina	51·2	51·3
silica	47·4	45·3
boric oxide	0·7	—
soda	0·7	—
zirconium	—	3·4
Fibre length, in.	Shorts to 1½	½–10 (average 2½)
Fibre diameter	Sub-micron to 10 (average 2½)	4–10
Specific gravity	2·73	2·73
Density: as received	Up to 4 lb./ft.³	Up to 4 lb./ft.³
recom. packing	6 lb./ft.³ min.	Up to 4 lb./ft.³
Melting point, °C.	Above 1,750 *	1,750
Working temperature, °C.	1,250 approx.	1,260
Tensile strength, p.s.i.	—	180,000 (fine fibre)

* Material shows no tendency to melt or sinter even at 1,370 deg. C., but there is a gradual change from an amorphous glassy structure to crystalline at exposures over 1,100 deg. C., the change proceeding faster at higher temperatures.

TABLE 2. Thermal conductivity at a density of 6 lb./ft.³ (B.t.u. in./ft.² h. deg. F.) of Fiberfrax fibres

Mean Temp., °F.	Short Staple	Long Staple	Washed
500 (260°C.)	0·58	0·5	0·50
800 (430°C.)	0·90	—	—
1,000 (540°C.)	1·33	1·2	0·86
1,400 (760°C.)	1·89	2·0	1·45
2,000 (1,000°C.)	—	3·4	2·26

TABLE 3. Stability of Fiberfrax fibres in acid solutions (per cent loss in weight when leached for one hour)

Solution	Normal	Concentrated
Hydrochloric	0·34	0·28
Sulphuric	0·31	0·85
Phosphoric	0·28	0·50
Nitric	0·25	0·20
Acetic	0·16	0·27

easily be formed into a blanket-like shape using wire netting and other supporting elements for holding the fibres together. Such structures have proved successful as jet engine blankets, for example.

LONG STAPLE FIBRE BLANKETS—For the production of longer fibres a somewhat different technique and raw materials are employed. The raw batch in this case consists of 42·75 parts white Al_2O_3 ore, 49·75 parts white sand and 7·5 zircon. This mix is fused in an arc furnace, tilted to allow the molten material to pour from the furnace into a small stream that impinges on to the periphery of one of two 12-in. rotors, rotating at 4,200 r.p.m. It is claimed that fibres produced in this way have an average diameter of 4 microns, are up to 6 in. long and have a bulk density of 0·72 lb./cu. ft.

These serve as a highly efficient medium for the filtration of hot gases. Pads, mats and blankets made from long fibres are particularly useful for the filtration of radioactive particles from hot exhaust gases in atomic energy reactors and for the filtration of hot gases generated by chemical and metallurgical processes. Long fibres also have excellent sound-deadening characteristics and improved resistance to vibration; both properties are particularly useful in insulations in jet and rocket engine test cells, silencers for jet engine warm-up and I.C. engine mufflers.

BLOCKS, MOULDINGS, CASTINGS—Aluminium - silicate blocks are made of short Fiberfrax fibres and suitable fillers and binders capable of resisting high temperatures. These blocks are used to reduce hot wall temperatures in industrial furnaces, kilns and combustion chambers.

Several forms of rigid moulded shapes, such as boards or corrugated sheeting, have been recently developed. Some of these serve as liners, shields or loose plates for heating element wires. It has also been reported that rigid moulded ceramic fibre products can, because of their porosity, be impregnated by vacuum and immersion techniques with commonly available inorganic binders as well as rubbers and resins.[5] Castable forms of aluminium silicate fibres are also available as linings for pressure vessels, incinerators, drying lids and duct insulations. In such cases a special type of short, chopped and milled fibre, free from unfibrised material, is frequently employed. Chopped fibres are also finding use in brake linings and refractory cements.

PAPER—For the manufacture of papers a washed type of fibre has been developed characterised by freedom from unfibrised material.

Fiberfrax paper, manufactured by the Hurlbut Paper Co., is available in sheet and roll form in thicknesses of 0·020, 0·040 and 0·080 in. Approximately 5 per cent of organic binder is used in one type (series 970) to increase handling strength, but the binder burns out at around 150 deg. C. It retains its form and insulating properties up to

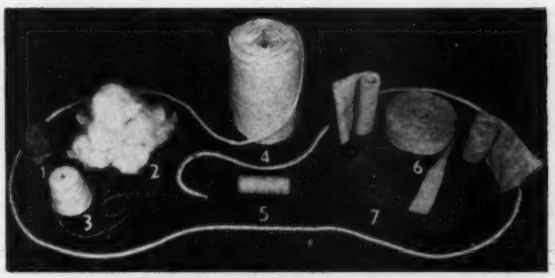

Fig. 2. Textile materials made from Fiberfrax aluminium-silicate fibres: 1, rock; 2, fibres; 3, sliver; 4, rope; 5, yarn; 6 and 7, tapes.

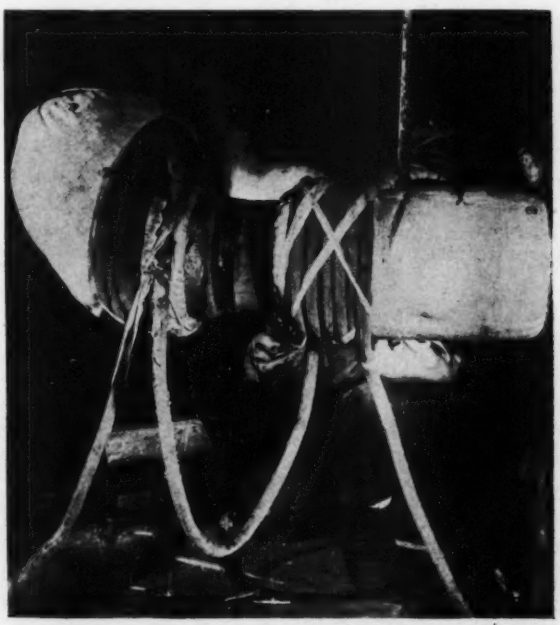

Fig. 3. Kaowool used in heat-induction pads during welding of a large-diameter pipe. The area adjacent to the weld is being preheated by means of the pads. Pads will be removed from the completed weld and stress-relieving completed.

TABLE 4. General properties of Kaowool

Composition, %	
alumina:	45·1
silica:	51·9
iron oxide:	1·3
titania:	1·7
magnesia:	trace
calcia:	0·1
alkalis as Na_2O:	0·2
boric anhydride:	0·08
Fibre length:	varies—max. 8 in.
Fibre diameter:	2·8 microns (average)
Use limit: continuous	1,100 deg. C.
short periods	1,260 deg. C.
melting point	1,750 deg. C.

TABLE 5. Thermal conductivity of Kaowool (B.t.u. in./ft.² h. deg. F.)

Mean Temp., °F.	3 lb./ft.³	5 lb./ft.³	10 lb./ft.³
400 (205°C.)	0·52	0·46	0·38
600 (320°C)	0·80	0·68	0·51
800 (430°C.)	1·15	0·94	0·66
1,000 (540°C.)	1·64	1·29	0·83

1,260 deg. C. Some established or possible applications of this paper are to be found in gaskets, separators, combustion chamber liners, cushioning in metallic honeycomb brazing, cushioning between metal and brittle ceramics during processing, refractory facings on metal, and in the production of bonded laminates.[6]

TEXTILES—Recent improvement in the average fibre length has made possible the development of a wide range of textile materials usually containing an admixture of 10-20 per cent of organic fibres. Some of these textiles are entering the traditional field of asbestos. Thus Fiberfrax rovings are used for insulation of heater cords, cables and electrical heating elements. Yarns are being produced by a normal carding process and, in order to facilitate this operation, 10 to 20 per cent of organic fibre is added. These burn off at elevated temperatures.

Some of the yarns are reinforced with wire or glass filaments. Nickel-chrome wire reinforced yarns can be exposed to temperatures as high as 1,100 deg. C., while those reinforced with glass filament can be exposed only to temperatures not exceeding 430 deg. C. Where tensile strength is not an important factor, the yarns may be exposed up to 1,250 deg. C. Fiberfrax yarns are frequently converted into a rope by twisting two or more ends together.

Rope made of this material has been successfully applied as thermal insulation in boilers, furnaces, hot gas chambers and for pipes and special shapes,[7] expansion joint packings, gaskets and seals in both controlled and normal atmosphere furnaces, and cores for braided products.

Several types of cloth and tapes based on wire or glass filament reinforced yarns have been also developed for high-temperature insulations, reinforcement of plastics, gaskets, seals and bag filters for collecting hot carbon and chemicals.

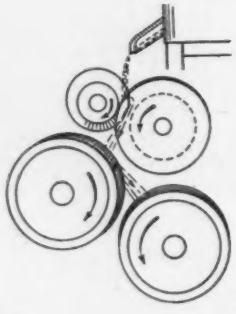

Fig. 4. Centrifugal spinning of refractory fibres, using plurality of rotating bodies.

Attempts have been made in the past to develop various composite fabrics. A range produced by the Philadelphia Asbestos Textile Corp. includes straight blend fabrics containing 50 per cent Fiberfrax and 50 per cent asbestos; others have a face woven from Fiberfrax yarn and asbestos backing. Fiberfrax-glass composite fabrics have also been produced.

KAOWOOL

This type of aluminium-silicate fibre is manufactured by the Babcock & Wilcox Co. from pure Georgia kaolin clay. Kaolin is a white powdery material of the following characteristics:

Approximate composition ... Al_2O_3; $2SiO_2$; $2H_2O$

Specific gravity ... ... 2·6

Fusion point ... ... Approximately 1,750 deg. C.

The manufacturing process for this fibrous product follows closely the pattern employed in the manufacture of other inorganic fibres. Kaolin clay is melted and the molten material blown into fibre. A pure white homogeneous mass of fibre is then collected on conveyors.[8]

Kaowool, like other alumina-silica fibres, is not recommended where it will be subjected to strong acids and alkalis for long periods. For very short periods of contact the resistance to cold acids is better than to hot acids or to hot or cold alkalis.

The makers' normal recommendation for maximum service temperature is 1,100 deg. C. for continuous usage and 1,260 deg. C. for intermittent usage. Because of their extremely low alkali content, they are not affected by water vapour at high temperatures.[9]

At the moment Kaowool is available in two forms: in bulk, for application where it is advisable and economical to pack or to blow the fibres into place; and in the form of blanket or felt. Recently, small quantities of continuous filament yarn have been produced experimentally.[10]

Applications

Kaowool is excellent for packing expansion joints in refractory linings. It has been successfully applied around headers and burner boxes and in other power plant applications. It is also used for packing expansion joints in special atmosphere generators; walls, roofs, around burners and in car tops in ferrous and non-ferrous heating furnaces; roof and wall sections of ceramic kilns; and in process furnaces in the chemical and petrochemical fields.

In blanket form it can be used as insulation in the preheating and stress-relieving of large welded units. The blankets are wrapped around the piece to be welded and the preheating induction coils are wrapped over the blanket.

Other uses in which it has been successful are as an insulator in jet engines and guided missiles, gas turbine mufflers, oven linings, high-temperature fans, annealing furnaces, inside metal enclosures, for high-temperature filters for the control of air pollution or for chemical recovery, steam valves and aeroplane unit heaters. It is also used as acoustic insulation in exhaust stacks of diesel and other internal-combustion engines.

KYANITE FIBRES

The crystalline aluminium-silicate minerals such as kyanite, sillimanite and andalusite are widely used as grogs in mixing for various types of high alumina or mullite refractories. Kyanite $3Al_2O_3$, $2SiO_2$ is the most abundant of this group of minerals. The Johns-Manville Corp. has

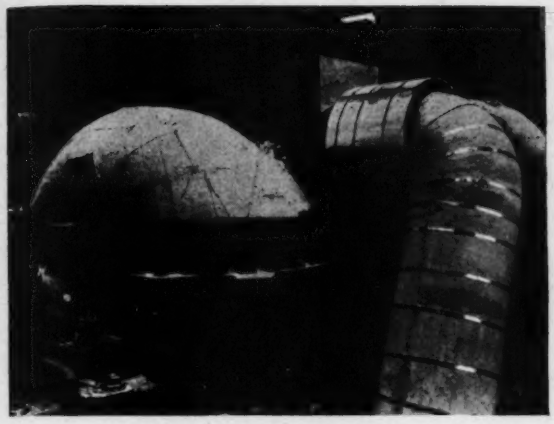

Fig. 5. Applied to the inlet valves of turbo-generators and the flange covers of steam turbines, Kaowool has proved to have a very long life.

Fig. 6. Johns-Manville Wrap-around blanket totally enclosed in metal foil with edges welded for protection against erosion, fuel penetration and vibration.

developed a process for the manufacture of kyanite fibres using an electric resistance furnace in which the molten liquid is a high-resistance conductor for fusing kyanite rocks. Recently, a good yield of fine, clean fibres has been obtained by successfully fusing and fibrising a blend of natural minerals comprising 100 parts kyanite and 6-12 parts silica.[11]

It is claimed[12] that the alumina-silica fibres produced from such a blend have good chemical and strength stability when used at temperatures at least as high as 1,100 deg. C.

The Johns-Manville Corp. has also developed a special centrifugal spinning apparatus (see Fig. 4) for the production of refractory fibres of great fineness and excellent length. This machine employs a combination of several rotating bodies, the centrifugal force of which is utilised for fibrising the molten material.

Main Uses

Johns-Manville aluminium-silicate fibres are marketed in the form of felt known as Cerafelt and as Thermoflex Wrap-Around blankets, constructed basically of ceramic felt, encased in heat-resistant metal alloys (stainless steel or Inconel) to provide protection against erosion, fuel penetration and vibration.

These Thermoflex blankets are highly flexible, permitting ready conformation to curved surfaces, and are commonly used in the aircraft industry as insulation for tail pipes, after-burners and engine cones. Other uses of Johns-Manville ceramic felts in the aircraft industry extend to foil-encased duct insulators, insulation of structural panels, such as engine compartments, fuselage panels and firewalls.

In addition to the numerous aircraft applications, these ceramic felts are serving practically every branch of modern industry wherever high temperatures are encountered. In a pre-clad form they find use in gas turbine engines, hot valve fittings, steam turbines, heated mechanical equipment, domestic and industrial furnaces, ingot pads, diesel engines, incinerators, driers, turbo-generators, forging covers and furnace nozzle cones.

This brief review of recent developments in the manufacture and applications of aluminium-silicate fibres clearly indicates the great potentiality of these relatively new materials.

Various other aluminium-silica minerals can be used alone or in mixtures for the manufacture of fibrous products. It has been proved, for example, that a blend of kaolin and bauxite is very suitable for this purpose. Fibres of excellent properties were obtained from the following composition.[9]

Calcinated Dutch Guiana bauxite	56·7 per cent
Calcinated kaolin grog	32·0 per cent
Raw kaolin	20·3 per cent

There is no doubt that other forms of alumina-silica materials are likely to be developed in the near future.

TABLE 6. General properties of J-M ceramic fibres

Fibre diameter:	1 to 5 microns, average 3 microns.
Weight:	1 cu. ft. loose fibres weighs approx. 4·5 lb.
Opatity:	Highly opaque to infra-red radiation
Heat resistance:	Not affected up to 1,100 deg. C. Above that, thermal stability influenced by temperature and length of exposure.
Chemical stability:	Non-alkaline and contains no sulphur.
Nuclear application:	It will not act as a moderator in the presence of nuclear fission. Highly suitable for nuclear energy field, either as thermal or sound insulation, or as a filtering medium

TABLE 7. Thermal conductivity of J-M ceramic fibres (B.t.u. in./ft.² h. deg. F.)

Mean Temp., °F.	3 lb./ft.³	6 lb./ft.³	12 lb./ft.³	18 lb./ft.³
300 (150°C.)	0·39	0·35	0·34	0·32
600 (300°C.)	0·65	0·54	0·49	0·45
800 (430°C.)	0·89	0·71	0·61	0·55
1,000 (540°C.)	1·16	0·92	0·75	0·66

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12. B.P. 728,354 (Refractory Fibre).

CURRENT TRENDS IN MACHINE TOOL DESIGN

A special report of some outstanding British and other exhibits seen at the sixth European Machine Tools Exhibition at Paris

AT the latest machine tools show which has just closed in Paris, sixty-seven British exhibitors, out of a total of 1,000 from nine countries, led the field in automatic control equipment. They also compared favourably in rationalised machine design, accessories and quality of materials, although continental manufacturers provided plenty of evidence of the experience, skill and research which they have put into the industry.

Several new control systems made their début at the exhibition. One which aroused great interest was the new Ferranti Mk. IV transistor/hydraulic control for three-dimensional continuous-path machining. The complex information required for this type of work is processed by a digital computer at one of the Ferranti centres and recorded on magnetic tape. An improved method of recording allows three hours' machining time on one tape, and the fully transistorised electronic circuits are built up from standard interchangeable units for easy maintenance. Hydraulic servo-motors, developing up to 3 b.h.p., are used for machine drive, as they have greater stiffness than the electric servos previously used. The measuring system is based on photo-cell scanning of shadow bands from a pair of stainless-steel diffraction gratings associated with each machine axis, and feedback is applied to eliminate transmission errors. A Tapemaster vertical drilling machine equipped with this system was demonstrated machining intricate components which would normally require complicated and expensive copy masters. The Contourmatic contour milling machine, made by High Precision Equipment Ltd., was designed for optimum performance with the Mk. IV control and combines very high precision with high spindle speeds and feed rates for a low capital cost. The optical measuring scales on this machine are totally enclosed by a concertina cover to prevent ingress of dirt and swarf.

Examples of two-dimensional co-ordinate control systems which do not require an external computer included the Ferranti numerical positional system, controlled by punched tape or manually-operated dials, operating an Atlantic co-ordinate drilling table at very high traverse rates; a new low-price system by E.M.I. of the dial and tape analogue type, which was shown automatically positioning a 30-in. rotary table to an accuracy of three seconds of arc and repeatability of one second for an unlimited number of angular settings; and the B.T-H. Two-Co-ordinate setting system, operated by punched card and dial with a measuring system based on magnetic alloy bars plugged at 1-in. centres with non-magnetic inserts, which was shown controlling a large Kearns horizontal boring and milling machine.

Societé Genevoise Ltd. had their very impressive automatic repeating device for their best Hydroptic jig borer. The co-ordinate settings on this very high quality machine are derived from two nickel-plated steel scales machined and engraved to the precision of absolute standards, and the operator can set to the inherent scale accuracy with micrometer dials and optical projection readings. The repeating device records the operator's initial settings on rotating magnetic cylinder memories, from photo-electric microscope readings fed to transistor amplifiers and phase comparators. During automatic machining the recorded information is transmitted through synchros to the electrical switchgear, so that the machine saddle undergoes gradual reduction of traversing speed and is finally stopped without overshoot by the photo-electric controls. The accuracy of repetition is within 0·00004 in.

The increased trend to the "building block" principle in machine tool design was an important feature at the exhibition. At least one British firm, T. S. Harrison Ltd., have been able to market their new small milling machine at a competitive price (even in Germany!) by the intelligent application of this principle.

An interesting new machine from Germany was the Elgar-Record automatic gas brazing machine. This consists of a rotating table which carries twenty rotary plates round its periphery. Blowpipes fed with fuel and oxygen are mounted on an adjustable vertical support column and each plate rotates in the vicinity of the flame. A single operator at the front control panel can produce 2,500 parts per hour.

James Neill Ltd. displayed the latest addition to their Eclipse range of chucks: a permanent electro-magnetic chuck designed to use the full value of remanent magnetism. A number of permanent magnets in the chuck are surrounded by coils which magnetise them to saturation so that workpiece and holding magnets are magnetised together.

To meet the increasingly exacting demands of modern high-speed machine tools, the French firm of Nadella were offering their Delta super-precision needle bearing. In addition to the usual advantages of high-precision needle bearings, the Delta type allows adjustment of radial play by a simple movement of a threaded and slotted taper sleeve over the outer ring of the bearing; or, alternatively, by adjusting the pressure of a shoe with a setscrew of differential pitch. Calibrated preset-loading can also be obtained by including a screw and leaf spring.

Another French firm, Ugine-Carbone, announced a new ceramic material, Ceroc, for cutting tools, which is claimed to have excellent performance on the toughest steel alloys even at the highest cutting speeds. It is also stated to be very resistant to shock and to have a long life.

S. Handel, A.M.I.E.E.

The new E.M.I. electronic positioning control system, fitted to a specially designed co-ordinate table, was seen at the Paris exhibition used on a Grimston drill. Cost is approximately £1,650.

CHOOSING METALS AND ALLOYS FOR CREEP RESISTANCE

by M. G. GEMMILL, B.Sc., A.I.M.*

Considerable attention is currently being paid to creep because of the high temperatures at which metals are used. This article discusses the properties of suitable alloys

CREEP of metals can be simply defined as plastic deformation with time under a constant stress. For steels this is not a factor of importance until operating temperatures exceed about 400 deg. C.; for light alloys, however, it is important at temperatures not very much above room temperature, while in one common metal, lead, it occurs at room temperature.

Faced with the problem of having to use a metal known to deform continuously under a normal design stress, the engineer requires to know what degree of deformation can be expected and thus tolerated; over recent years this has led to an appreciable amount of creep testing. A typical family of creep curves is shown in Fig. 1; these illustrate the three stages of creep and could be viewed as tests made either at one stress and variable temperature or at one temperature and variable stress.

Equally, it must be known what elements can be added to a metal to improve its creep strength. In the case of steam power plant this has resulted in the last twenty years in additions of molybdenum, chromium and vanadium to mild steel. Compositions of established materials thus developed are detailed in Table 1, along with that of a more recently used austenitic steel.

It has to be admitted that such changes in chemical composition and, in fact, much of the alloy development which has produced materials for gas turbines and steam power plant has been empirical, as demand for properties outstripped fundamental knowledge of how to achieve them.

Consideration of the very different microstructures that can be obtained in steel, as illustrated in Fig. 3, makes it hardly surprising that the heat treatment, and hence the microstructure, of steels can be just as critical as changes in chemical composition in affecting creep strength.

When one is faced with the choice of a creep-resistant material it is usually necessary to know the following factors:

1. Creep resistance in relation to application envisaged.
2. Mechanical properties at room and operating temperature.
3. Weldability.
4. Corrosion resistance.
5. Physical properties.

Assessment of creep resistance will be discussed further when considering test methods. Mechanical property requirements at room temperature obviously may affect the choice of material for high-temperature service, while at both room and operating temperature good ductility should be demanded. Weldability considerations will, of

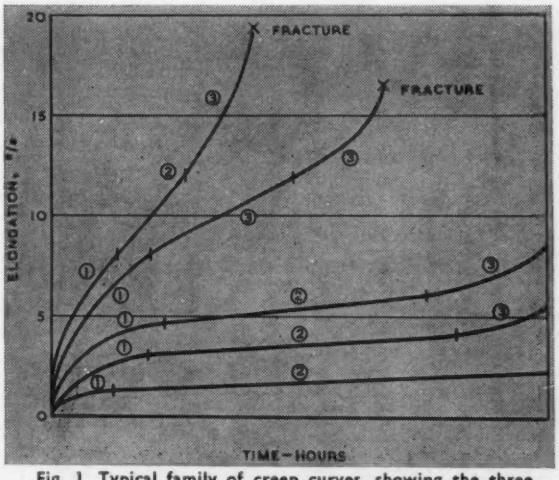

Fig. 1. Typical family of creep curves, showing the three stages of creep.

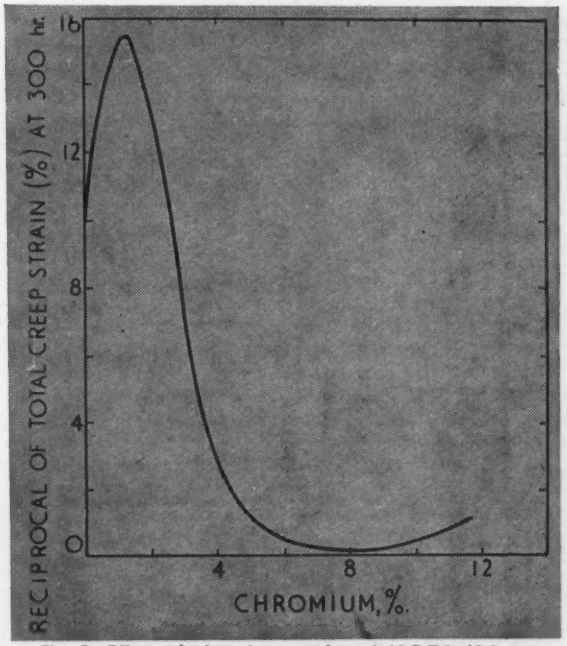

Fig. 2. Effect of chromium on forged H.G.T.3 (0·2 per cent C, 0·5 Mo, 0·5 W and 0·8 V).[1]

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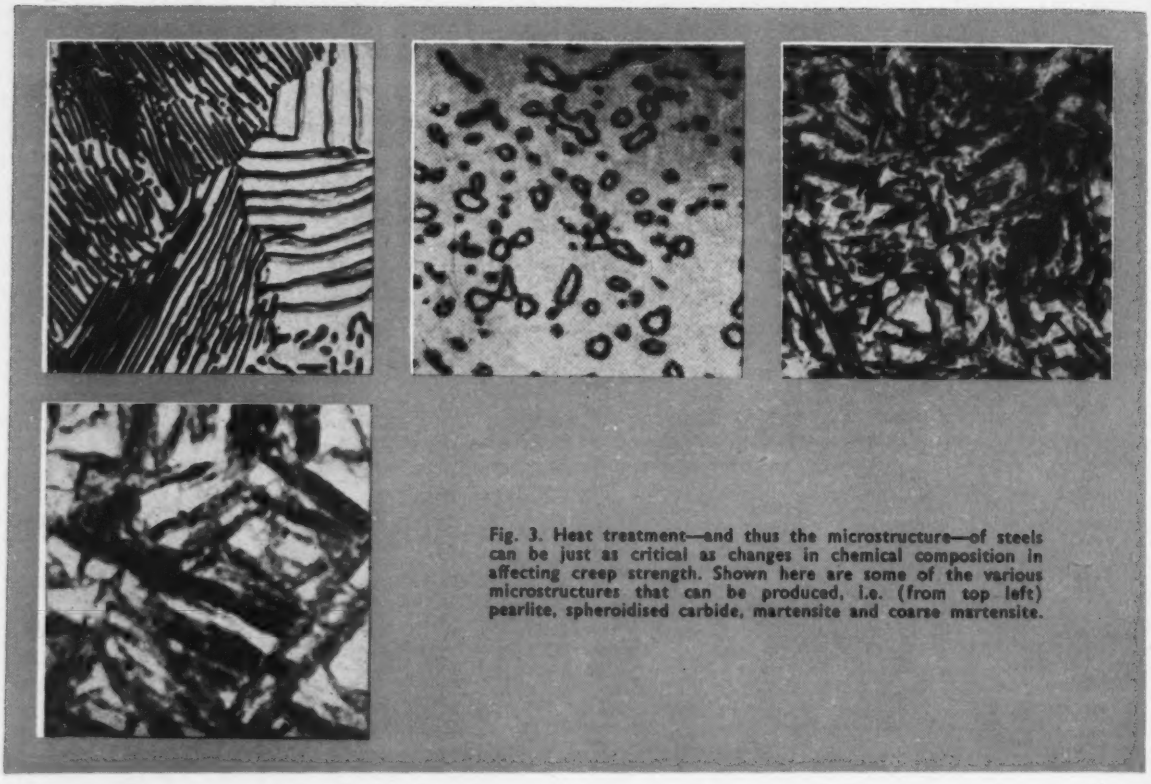

Fig. 3. Heat treatment—and thus the microstructure—of steels can be just as critical as changes in chemical composition in affecting creep strength. Shown here are some of the various microstructures that can be produced, i.e. (from top left) pearlite, spheroidised carbide, martensite and coarse martensite.

course, only arise in certain cases, but it is important to remember that welding a creep-resistant material might seriously affect its stress-carrying capacity unless suitable post-welding treatment is carried out. Corrosion resistance is often a concomitant of creep strength, as, for example, in superheater tube steels in a power station boiler; but, as Fig. 2 indicates, the addition of chromium to confer oxidation resistance can result in a marked reduction in the creep strength. Physical properties of interest are thermal expansion and conductivity characteristics, important in relation to the thermal stressing often inevitable in engineering applications.

Creep Testing

Historically, the creep test has developed from a group of many "short-time" tests ranging from twenty-four hours to a week. These tests were devised for quick sorting of materials and were based on the erroneous idea of a "creep limit", i.e., a stress below which creep would not occur. A little later the high sensitivity "long time" test began to be made using equipment capable of measuring creep rates of the order of 1×10^{-8} strain/hour. "Long time" in this sense usually meant up to 1,000 hours, and the property measured was the creep rate and creep strain at this time. Such a test was seldom made beyond a plastic extension of 1 per cent and served the wartime interest in jet aircraft steels quite well, as it had the limited pre-war development of steam plant materials. Since the war, however, increasing attention has been paid to steam plant materials and, since their expected service life is about 100,000 hours, much longer test periods have become necessary to avoid such extrapolation from, say, 1,000-hour tests. Also, it began to be appreciated that the stresses to cause fracture in a material were of perhaps more relevance to many applications than the stresses to cause a specific degree of plastic deformation such as 0·1 or 1 per cent. Thus, at the present time creep testing involves tests either to various strain levels in high sensitivity machines or to rupture in units of lower sensitivity. Test durations are now closer to 10,000 hours than 1,000 hours, while quite a few tests are being made up to 100,000 hours.

One aspect of creep testing which has, in this country, not yet received the attention it deserves is the scatter band of properties for one type of material. Effort has so far been expended largely on detailed investigation of several casts of steel rather than on a more widely based consideration of the variation to be expected from cast to cast of nominally the same composition.

The question of extrapolation can be simplified into one of two methods generally used. Either a series of tests can be made at one temperature under various stresses or at one stress and variable temperatures. The use of the stress-acceleration method is perhaps preferable, since it corresponds with the practical danger of a stress-raiser condition, while the use of temperature as a means of quickening time dependent behaviour can be misleading due to metallurgical changes which are not necessarily the same at each temperature. It is for this reason that extrapolation formula based on time and temperature, while of value, should be used with caution.

Having obtained stress values for either a specific

TABLE 1. Compositions of metals developed for steam power plant

Steel Type	Carbon	½% Mo	1% Cr, ½% Mo	½% Mo, ¼% V	2¼% Cr, 1% Mo	18.12.1 Cr, Ni, Nb
Carbon	0·1	0·1	0·1	0·1	0·1	0·1
Manganese	0·5	0·5	0·5	0·5	0·5	1·0
Silicon	0·2	0·5	0·5	0·5	0·5	1·0
Chromium	—	—	1·0	—	2·25	18·0
Molybdenum	—	0·5	0·5	0·5	1·0	—
Nickel	—	—	—	—	—	12·0
Vanadium	—	—	—	0·25	—	—
Niobium	—	—	—	—	—	1·0

TABLE 2. Comparison[3] of design stresses with A.S.M.E. boiler code, p.s.i.

Temp.		British Data			A.S.M.E. Boiler Code
°C.	°F.	(a)	(b)	(c)	
550	1,022	14,800	—	—	13,300
600	1,112	8,000	9,700	10,500	9,700
650	1,202	4,700	4,500	5,600	5,000
700	1,292	2,500	2,300	2,800	2,400
750	1,382	1,300	1,400	1,650	1,300

(a) 60 per cent of average 10^5-hr. rupture value.
(b) 80 per cent of minimum 10^5-hr. rupture value.
(c) 100 per cent of 1 per cent plastic strain in 10^5-hr. value.

amount of strain or for rupture, it is necessary to arrive at design stresses of use to the engineer, and such values are shown in Table 2 for the same austenitic steel as mentioned previously. The three methods used for design stress calculation are based on A.S.M.E. Boiler Code practice. In summary, the present state of knowledge on the subject of creep resistance would suggest that both long-time testing and longer-time extrapolation will be with us for some years to come: what might be questioned is whether such tests, valuable although they are in placing various materials in some order of merit, are equally suitable in doing so for all known conditions of industrial application.

Material Factors

In choosing examples of service requirements and factors governing material choice, it might be useful to consider two widely differing but equally important power units, one being an aircraft gas turbine engine and the other a steam power station operating under the most recent high temperature-high pressure cycle.

AIRCRAFT ENGINE—A diagrammatic representation of an aircraft engine—the Rolls-Royce Dart—is given in Fig. 4. Starting at the inlet end, the incoming air encounters either a centrifugal compressor as here or, more commonly, an axial compressor. In this component the creep resistance required is usually expressed in terms of tolerable plastic strain, which is understandable when a safeguard is required against the possibility of blade rubbing. This is therefore an example of the need for low deformation rather than rupture data. Having passed through the compressor, combustion takes place in the combustion chambers, usually radially disposed around the engine body. These "flame cans" are made of thin sheet metal in which numerous stress raisers occur by virtue of the many entry ports drilled in the metal. There the material requirements are rather complex and not always clearly defined. It is evident, however, that reliance entirely on creep resistance would be wrong and, in fact, the material most commonly used for this application—the nickel-based alloy Nimonic 75—is selected as much for its good formability and corrosion resistance as for its creep strength.

After combustion the gas stream passes into the turbine system and here we encounter the creep problem in regard to the highly stressed turbine disc and also the turbine blades. The latter is highly stressed and also exposed to very high gas temperatures, giving the most severe combination of stress and temperature undergone by a metal in such an engine. A material suitable for such turbine blade service must possess a high level of creep strength, associated with good scaling resistance and adequate ductility, the latter being particularly important when "fir-tree" root fixing is necessary.

A suitable turbine disc material should happily combine good mechanical properties at the highly stressed hub with good high-temperature strength at the hotter rim seating the turbine blading. It is not surprising that steels for these two components have proved difficult to develop, whilst the components themselves have been subjected to most stringent acceptance tests (see Fig. 5).

Finally the gas stream leaves the turbine via the jet pipe, once more an assemblage of sheet metal operating at a very high metal temperature. There creep strength is relatively unimportant in comparison with scaling resistance.

The preceding example has dealt with a very compact power unit: power production in terms of a steam power station is a matter on another scale, both in terms of plant size and plant life, usually around 100,000 hours in contrast with several thousand flying hours for an aero engine.

STEAM POWER STATION—In a steam power station, the mild-steel generator wall tubing which encases the boiler operates at temperatures which are much too low to make creep strength a factor in their selection. It is only when localised overheating takes place that failure due to creep might occur. The first region in a modern boiler demanding specifically creep-resisting materials is the superheater, in these instances where design metal temperatures exceed about 450 deg. C. The types of steel used have been referred to earlier; typical mechanical properties given by these materials are shown in Table 3. These steels have to withstand the scouring action of the hot boiler flue gases, the thermal gradient induced from the outer wall to the cooler inner wall through which the steam is passing as well as the design pressure of the steam cycle involved. Failures of tubing which occur can be due to overheating as a consequence of, say, steam starvation: this gives the type of fracture shown in Fig. 6, and the appreciable duc-

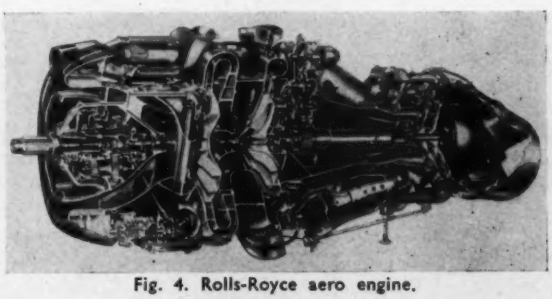

Fig. 4. Rolls-Royce aero engine.

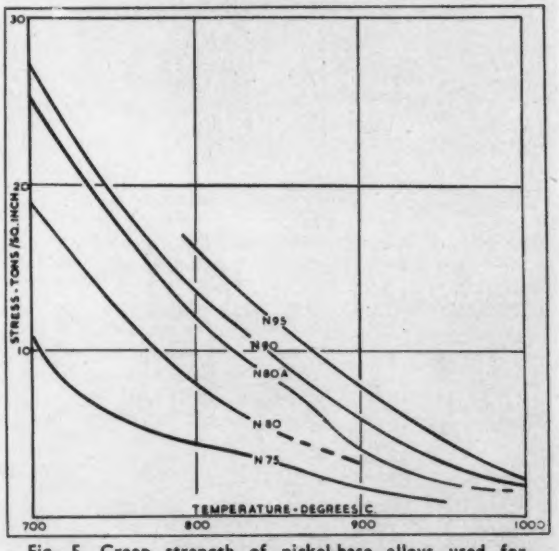

Fig. 5. Creep strength of nickel-base alloys used for turbine blades of Rolls-Royce Dart engine (100 hr. to fracture).

TABLE 3. Typical mechanical properties of steel types

Steel Type	Carbon	½%Mo	1% Cr, ½% Mo	½% Mo, ¼% V	2¼% Cr, 1% Mo		18.12.1 Cr, Ni, Nb
U.T.S., t.s.i.	27·0	28·0	34·4	32·0	41·4	32·6	36·8
0·1% Proof Stress t.s.i.	19·3	12·5	13·0	20·6	36·0	15·3	12·5
Limit of proportionality, t.s.i.	17·7	4·3	5·0	18·0	32·0	5·0	6·4
Elongation, % on $4\sqrt{a}$	45	47	41	28	30	40	59
Reduction of Area, %	70	73	63	58	75	53	72
Izod impact value, ft./lb.	70	87	77	30	95	36	104
Heat treatment	920°C. air cooled			950°C. A.C. tempered 690°C. 5 hr.	900°C. A.C. tempered 735°C.	900°C. furnace cooled	1,050°C. air cooled

tility prior to rupture should be noted. Alternatively, but less commonly, a tube may fail by creep to give the type of fracture shown in Fig. 7; in this case very little deformation, and hence little warning, is given prior to rupture.

From the superheater the steam goes through a high-pressure piping system to the turbine. High-pressure piping represents a section of the plant where only small dimensional changes can be tolerated during service and where regions of stress concentration can lead to failure in, for example, welds. Since the latest steam plant operates on the "unit" principle, i.e., one boiler, one turbine, the increasing importance of the interconnecting piping is obvious.

The steam in its passage through the turbine undergoes an appreciable pressure drop with resultant volume expansion and, in the final low-pressure stages, it becomes wet. This results in differing requirements in respect of turbine blading to provide corrosion and erosion resistance, in addition to stress-carrying capacity. Many of the turbine blades used are made from a 12 per cent Cr steel which, by proper heat-treatment control, can meet satisfactorily the requirements of mechanical strength and ductility in the root and hardness, to resist erosion of wet steam, at the tip.

The increasing temperatures and pressures being used in the latest steam plant have meant the use of alloy steel in both high- and low-pressure rotors. This development has faced the steelmaker with the difficulty of providing creep-resistant materials in large cross-section without any significant loss of mechanical properties throughout.

Fig. 6. Superheater tube—failure by overheating.

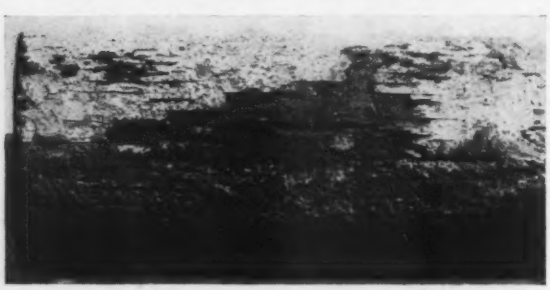

Fig. 7. Superheater tube—failure by creep.

In addition to the moving parts of the turbine, such components as casings and diaphragms are also demanding the use of creep-resistant materials. When a casting is involved there is sometimes a difficulty in choosing the most suitable material, since castability and ease of repair welding become factors to be weighed against creep resistance on its own account. These points are of particular relevance to H.P. turbine casings.

In auxiliary plant, creep-resistance requirements have led to the use of cupro-nickel alloys in place of copper in feedwater heaters.

One item of steam power plant in which creep resistance plays an important part is bolting. Although increasingly supplanted by the use of welding, bolts capable of resisting high-temperature and pressure conditions are still necessary for such items as turbine casings. This application involves the problem of stress relaxation in which the overall length of the stressed component remains unaltered whilst the stress in it is diminished by plastic deformation.

Until fairly recent times the engineer, when faced with the choice of various creep-resistant materials, has tended to rely chiefly upon data giving the relative order of stress-carrying capacity, determined either on a plastic strain or rupture basis. To these stress values has been applied the traditional tribute to ignorance known as the factor of safety. It is becoming increasingly appreciated that many service failures, whether it be in the window frames of a jet aircraft, in the L.P. or H.P. rotor of a steam turbine, or in the weld region of a high-pressure pipeline, owe their occurrence to an unfortunate combination of stress concentration due either to poor design or fabrication procedures with a material possessing little ability to relieve internal stress. When one is dealing with creep-resistant materials, essentially produced not to deform plastically, it is clear that such dangers are correspondingly greater; it therefore becomes necessary to look for associated criteria for guidance in material selection. One such aspect is the ductility exhibited by the material at its operating temperature range. Another aspect is resistance to the thermal shock which inevitably arises when dealing with equipment running under variable load conditions.

It may well prove that a more accurate assessment of materials under such conditions will be found on a basis of tolerable strain rather than by complete reliance on stress values whose primary purpose should be to place the various materials in an initial order of merit.

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RESISTANCE WELDING IN RELATION TO DESIGN

These welding processes can offer the designer definite advantages in certain applications. Here the author discusses some of the potentialities and growing uses

by E. J. FRENCH, B.Sc., A.M.I.E.E.*

THE resistance welding processes are among the most versatile of all metal-joining methods. Often one or other of these processes may be applied, with otherwise little or no change in the design of the product, in order to achieve faster and more efficient production. In some cases, however, unsuitable design hinders the achievement of high quality welding, and it is therefore helpful for the designer to appreciate the main features of the resistance welding processes and to understand in what ways they differ from other welding methods.

In resistance welding a very large electric current is passed between the parts to be joined. Heat is generated by the passage of this current through the resistance of the components and through the surface resistance which exists where they are in contact, and the heated components are forged together by an applied force. The heat is produced mainly at, or close to, the interface between the components, and since the welding operation is very rapid the heating is localised. For this reason, there is much less trouble from distortion than is often the case with other welding processes in which the heating is slower, causing relatively large temperature rises in parts of the components where heating is not required.

The advantages of the resistance welding processes are many. Highly skilled operators are not required. Welds can be made in a fraction of a second, leading to high productivity. The processes lend themselves to automatic control and may readily be incorporated in production lines. Problems due to distortion and overheating of components are avoided. For these reasons resistance welding is now very widely used, particularly in the mass-production industries, but even where short production runs are involved its use is spreading rapidly because of the very large savings that can be made.

There is an extensive literature to guide the production and planning engineer and the designer in the selection of the right resistance welding process and in its correct use. J. E. Roberts[1] has recently described the processes in some detail, and further assistance in specifying welds as regards their type, size and position may be obtained from the British Standard on welding terminology.[2]

Spot Welding

The most widely used of the resistance welding processes is spot welding, by means of which lap joints may be made in sheet or strip metals. The components to be joined are placed face to face between two copper or copper alloy electrodes, which not only carry the welding current, but also serve to transmit the welding force. Fig. 1 shows the general arrangement, and further information upon supplying and applying the current including electrode shapes and dimensions, is readily available.[1] In addition, codes of practice[3, 4, 5, 6] give recommendations regarding welding conditions generally, and it is important to note the existence of a number of British Standards[7, 8] on the subject.

Spot welding may be successfully applied to a wide range of ferrous and non-ferrous metals, including steels and stainless steels, nickel alloys, aluminium, magnesium and titanium. A notable exception is copper, which has physical properties equivalent to those of the electrodes—its low resistivity causes low heat generation by the welding current, and its high thermal conductivity causes what heat is generated to be dissipated rapidly. Hence it is very difficult in this case to build up sufficient heat at the interface for welding to occur. However, some success has been achieved in spot welding thin copper by using tungsten copper or molybdenum-tipped electrodes. These remarks do not, of course, apply to some copper alloys which are readily spot welded using normal techniques.

It is desirable that material intended for spot welding should be clean and free from scale and grease. This requirement is less stringent when welding, say, a low carbon steel than in the case of aluminium alloys, where rigorous cleaning techniques must be observed and where even a finger mark on the surface of the sheet can lead to a faulty weld. Again, certain materials require special techniques, calling for more complex control equipment. The high-strength aluminium alloys require what is known as a dual load cycle, that is, in addition to the normal welding force applied by the electrodes, a heavy additional forging force must be applied at the right moment during the welding cycle in order to eliminate cracks and cavities.

Another example of a complex weld cycle is in the case of hardenable steels: the cooling of a spot weld is very rapid indeed, and in thin material is more severe than a water quench. For this reason, steels with carbon contents exceeding about 0·15 per cent (0·12 per cent for thin sheets) give hard, brittle spot welds. Most spot welding is carried out on low carbon steel of deep drawing quality which does not harden severely even under these conditions, and a simple weld cycle with a single current impulse suffices, but with higher carbon and low alloy steels it is desirable to heat-treat the spot weld between the electrodes of the welding machine. Modern electronic control equipment facilitates this, and the normal sequence of such operations is represented in Fig. 2. There are several ways of assessing the ductility of spot welds, and hence of deciding whether or not post-heat treatment, as it is called, is necessary.

Spot weld ductility has little effect on the shear strength of the weld, values for which are quoted in the codes of practice already mentioned. As an example, the accepted average shear failing loads for spot welds in low-carbon mild-steel sheet range from 530 lb. in 24-s.w.g. material to 7400 lb, in ¼-in.-thick sheet. Owing to the notch effect at the periphery of a spot weld, the tension strength of such a weld is very sensitive to changes in the ductility of the material near the edge of the fused zone. The ratio of the strength of a spot weld loaded in tension to the

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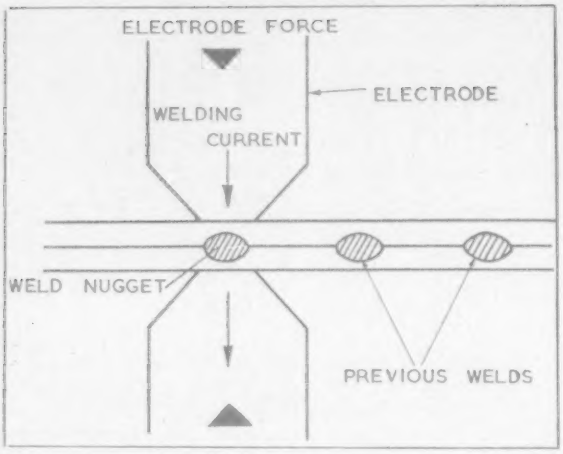

Fig. 1. Principle of spot welding.

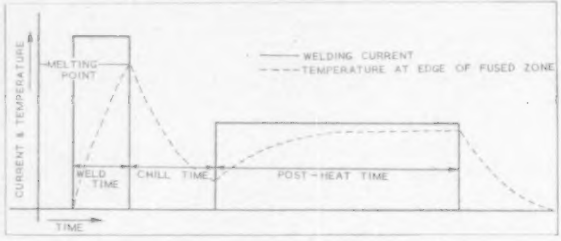

Fig. 2. Programme control in spot welding.

strength of a similar weld tested in shear gives a value known as the "ductility ratio". This may be as high as 80 or 90 per cent for a spot weld in a deep drawing steel, but for welds in steels producing brittle structures the ratio can fall to 20-30 per cent. Such a low value is an indication of the need for post-heat treatment, particularly if the weld is likely to be stressed in tension or subjected to fatigue or shock loading. Such matters have been considered in more detail elsewhere.[9]

The simplest type of spot welding electrode[10] has a straight shank and a welding tip in the form of a truncated cone. It is rigid and strong, the welding face is backed up by adequate material and the internal water cooling, an important feature of spot welding electrodes, can circulate freely behind the welding face. Because of these reasons, as well as the fact that it is easy to machine and maintain such electrode shapes, it is preferable, where possible, to design components in such a way that this type of electrode may be used. However, other shapes, such as angle, offset and crank, are commonly and successfully used in conjunction with various types of electrode holder and adaptor. This allows spot welds to be made in otherwise inaccessible positions. Fig. 3 gives some examples.

Although the use of special electrode assemblies may allow the electrodes to close upon the work at the desired position, the design of the components may yet make them unsuitable for spot welding. During the formation of a spot weld the molten weld nugget, which is under heavy hydrostatic pressure, is contained by a peripheral band of solid metal; if the weld is made too close to the edge of a component, this seal is weak, and breaks down, allowing expulsion of molten metal to occur from the weld nugget. This results in low strength welds of poor appearance. It is therefore very important to bear in mind the minimum edge distance recommended in codes of practice. The minimum spot spacing, also specified in codes of practice, is necessary, because if a spot weld is made close to an already existing spot, part of the current is shunted through the existing weld, and so does not contribute in forming the new one. The minimum spot spacing is that spacing for which the recommended welding conditions will give acceptable welds. However, by increasing the heat input, it is possible to make spot welds very close together—so close, in fact, that they overlap. This is known as stitch welding, and can be useful in forming a leak-proof joint, where, for some reason, seam welding is not possible or is made difficult by the shape of the parts.

There are other variations of the spot welding process. Series spot welding, defined[2] as spot welding in which two or more welds are made simultaneously in electrical series, may be employed in a variety of ways, as shown in Fig. 6. An electrode assembly for series welding, in which a copper backing bar is used against one side, will leave no surface marking on that side of the work. Another way of eliminating surface marking on one side is by using a flat or large radius dome-type electrode against that side. Caution is necessary in specifying such arrangements, since if two sheets of similar thickness are spot welded using a larger electrode one side than the other, the weld nugget will no longer be distributed symmetrically about the interface, but will tend to favour the sheet against which the smaller electrode is placed, owing to the greater heating effect taking place there. Hence when welding dissimilar thicknesses it is much more difficult to leave an unmarked surface on the thin than on the thick material. Normally when two components of dissimilar thickness are to be joined, an electrode of tip diameter appropriate to the thickness is used against each sheet. In this way a weld nugget is formed about the interface rather than largely in the thicker sheet.

Projection Welding

Whereas in spot welding the current is concentrated by the geometry of the electrodes, it is the shape of the components being welded which concentrates the current in the case of projection welding, as indicated in Fig. 7. At the start of the welding cycle contact between the components is made by one or more projections which collapse as the weld is made, a separate individual weld resulting from each projection. Because of this the electrode tips can be large, as compared with spot welding electrodes, and because the required current density is therefore lower they can be made of a lower conductivity but harder wearing copper alloy. Thus projection welding has certain advantages over spot welding in that several welds may be made simultaneously, and electrode life is longer. In addition, projection welding can sometimes be employed where spot welding would be impossible because of the thickness or shape of one or both of the components. Another advantage is the lack of surface marking on at least one side of the welded article. Amongst the disadvantages of this process, it may be mentioned that because of the electrode shape the weld is not forged to the same extent as is a spot weld, and also it is not easy to carry out post-heat treatments in the welding machine, particularly where several welds are made at once.

It is obvious, then, that projection welding is not usually the best of methods for joining hardenable steels. For the same reasons as for spot welding, projection welding is not a suitable process for joining copper, and aluminium and its alloys present considerable difficulties, since the projections tend to disintegrate with explosive violence. Crosswire welding of aluminium has, however, been successfully carried out.[11] Low-carbon mild steel, stainless steels and many other materials are satisfactorily projection welded, and the process has certain advantages in the joining of dissimilar metals, since the projection may be located in the higher conductivity material in order to correct the heat balance.

In joining sheet metals the projections are raised on one sheet with the aid of a punch and die. Projection shapes are designed so that they may be produced easily by this process and also so that they will not collapse prematurely, but will withstand the welding force for long enough to allow the required heat to be generated by the passage of the welding current. Suitable projection dimensions have been determined for mild-steel sheet and this information, together with recommendations for welding conditions, may be found in published codes of practice.[5, 12] Phipps[12] has demonstrated a relationship between the weld strength per projection and the sheet thickness when projection welding low-carbon mild-steel sheet in accordance with his recommended conditions. For example, a shear strength of 1·5 tons per projection may be obtained between projection-welded 14-s.w.g. low-carbon steel sheets.

Sometimes it is necessary to make projection welds between inclined or curved surfaces. Under these circumstances some sliding action takes place between the components, and in order to prevent consequent destruction of the weld it is sometimes considered advisable to use an elongated projection, as shown in Fig. 4.

Apart from the making of lap joints between sheet-metal components, there are several other processes which may be classified as forms of projection welding. Studs may be welded to metal surfaces using a standard projection welding machine with one electrode recessed to accommodate the stud as shown in Fig. 7. In this case the shape of the head of the stud forms the projection which concentrates the current, and recommendations have been made regarding the most suitable shapes of head for the purpose[13] and suitable welding conditions. An idea of the success of this process may be obtained from the fact that a $\frac{5}{16}$-in. stud welded to 12-s.w.g. sheet steel gives a weld strength of 58 lb./ft. in torsion or 1·9 tons in tension. Values for other stud sizes and sheet thicknesses are given in codes of practice.[13]

Weld bolts, nuts and bosses of various types may be joined to sheet steel by projection welding. Where a leak-proof joint is required, the projection takes the form of an annulus—otherwise a number (usually three) of separate projections may be used. Such projections are formed during the manufacture of the components—they may be headed, forged, cast or machined. A range of weld nuts, bolts, studs and bosses is available commercially. Barnes[14] has developed welding conditions suitable for joining many of these types of projection hardware to low-carbon steel sheet and plate. The information given covers most

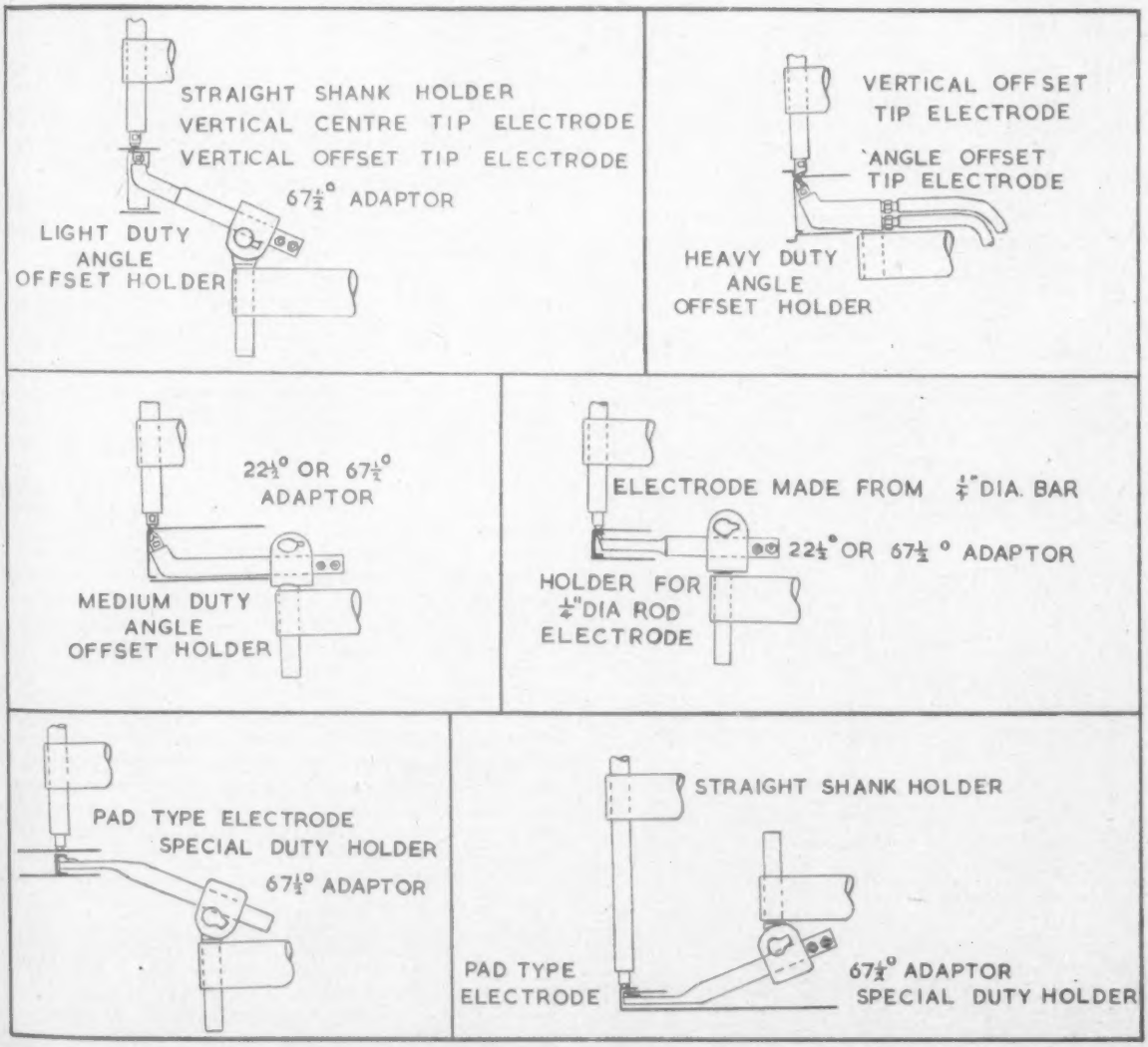

Fig. 3. Examples of possible combinations of Mallory standard holders and electrodes (Johnson, Matthey & Co.). The two types of electrode holder adaptors shown have recently been replaced by a single adaptor.

of the likely applications.

Another application of the annular projection is in joining tube to a flat surface. Bolz[15] describes how bevelling the inside of the tube, as in Fig. 8 (a), will minimise the amount of upset metal outside, whereas with the bevel on the outside, as in Fig 8 (b), there will be minimum obstruction within. The same author describes special coined projections for accurate heavy assemblies and gives typical designs suitable for joining ¼-in. and ½-in. plate. A depression is produced around the projection to accommodate the upset metal, the volume of this depression being about 70 per cent of the spherical volume above the surface of the plate.

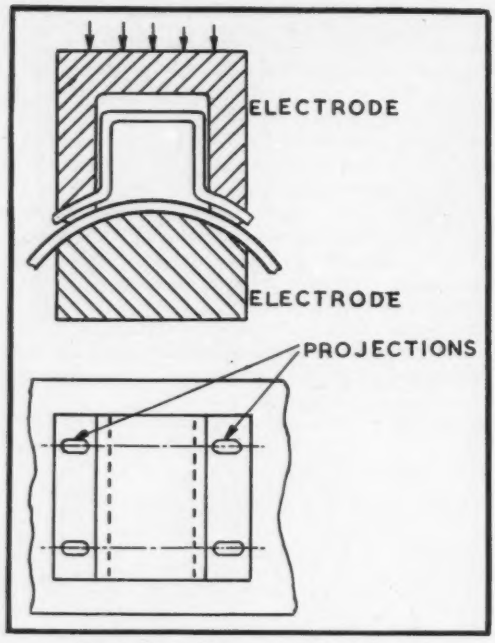

Fig. 4. Projections on curved surfaces.

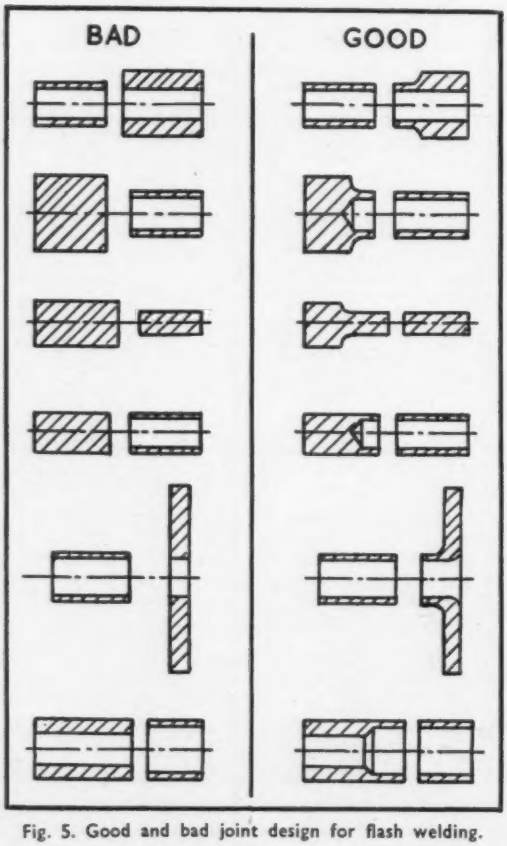

Fig. 5. Good and bad joint design for flash welding.

T-joints between sheet components may be made either by shaping the edge of one component to form the necessary projections, or else by pressing them in the other sheet. Cross-wire welding, often carried out on spot welding machines, is really a type of projection welding, since here also the geometry of the components concentrates the heating where it is required.

It has already been mentioned that projections must withstand the welding force until the required heat has been generated. It is also very important that the component opposing the projections should be sufficiently strong in itself, or should be sufficiently backed up by the electrode, to withstand the pressure of the projections, which otherwise will distort this component and force their way into its surface without forming satisfactory welds. Hence a design for projection welding must always allow reasonable access for the electrodes immediately opposite the projections on both parts being welded, except where the parts themselves are so designed as to provide the required strength during welding.

Seam Welding

Stitch welding, in which leakproof lap joints can be made between pieces of sheet metal, has been mentioned above. A similar result can be obtained by seam welding, in which the truncated cone-type electrodes are replaced by wheels, as shown in Fig. 9, resulting in considerably faster welding speeds. As well as applying the welding force and conducting the welding current to the work, the wheels are also used to drive the work through the welding machine. As for spot welding, current, electrode force and heat time are important variables, with the addition of cool time, or the time between two successive heat times, and also the speed at which the work is driven through the machine. Most materials which may be spot welded may also be seam welded. Roller-spot welding is a similar process, the only difference being that in this case the weld is intermittent.

Other interesting variations of this process are mash seam welding, in which the two sheet metal components are welded together with a small amount of overlap and welding conditions are adjusted so that the final thickness of the weld is about equal to that of a single sheet, and metal finish seam welding, described by Allen and Begeman,[18] in which the electrode shape is so arranged that, after welding, the edge of one sheet projects above the surface and may be machined away, leaving a perfect finish on one side of the weld.

Recommended seam welding conditions for a number of materials are available in the literature[5, 19] and these include values for the minimum distance which should be allowed from the weld to the edge of the material. For the same reasons as in spot welding, these conditions should be observed except, of course, under special circumstances, such as are required for mash seam welding where the overlap is reduced to about one and a half times the sheet thickness.

Generally, the main requirement for a seam weld is that it should be pressure-tight. Seam welding conditions may be checked by using the pillow test in which two flat sheets are placed face to face and then welded around the edge. Pressure is applied to the space between the plates from a hydraulic system by way of a pipe welded to connect with a hole in one of the sheets. Any failure should be in the parent metal rather than the weld.

Resistance-Butt Welding

As defined in British Standards,[2] resistance-butt welding is:

"Resistance welding in which the components are butted together under pressure, and current is allowed to flow until the temperature is reached at which upset metal is produced and the weld is completed."

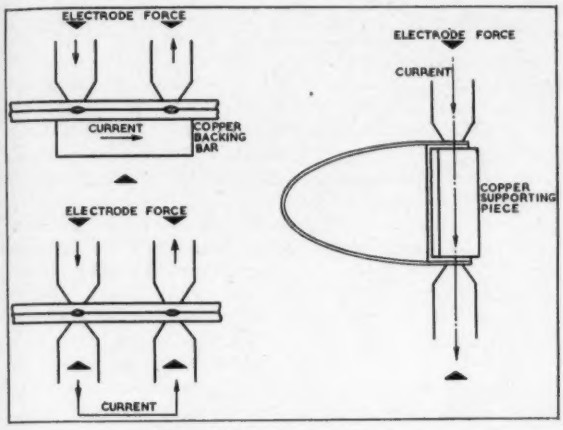

Fig. 6. Series spot welding.

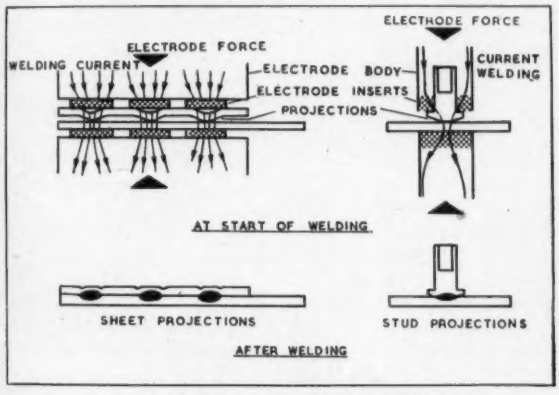

Fig. 7. Principles of projection welding.

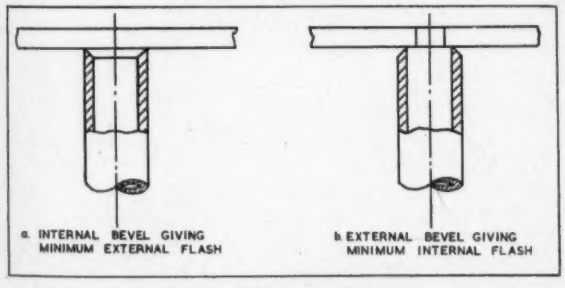

Fig. 8. Preparation of tubes for projection welding.

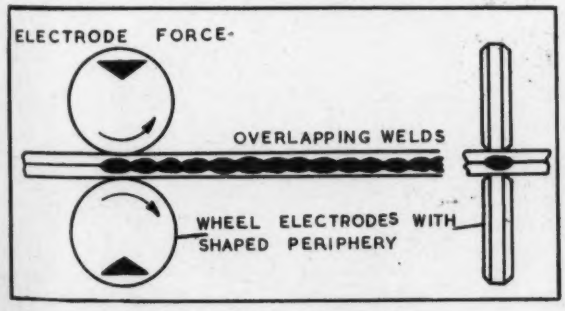

Fig. 9. Principles of seam welding.

Resistance-butt welding is used principally for joining wires and small-diameter rods, but it may also be used for joining tubes, provided that some restriction of the bore due to the upset is permissible. If welding is to take place, some upset must always occur, and an allowance must be made for this in part dimensions.

Facilities are sometimes provided on butt welders to allow annealing after welding. This is useful when welding hardenable steels.

By the use of special electrode assemblies it is possible to adapt a spot welder to produce tee butt joints in rod or wire.

Flash Welding

This process differs from butt welding in that the initial pressure between the components is low, and consequently heating is caused by the welding current flowing through localised points of contact. The very heavy current density causes local melting and even vaporisation of the metal, which is expelled. One component is moved slowly forward, establishing new points of contact as the old ones are destroyed and causing a shower of sparks to be ejected. When the welding temperature is reached the components are forged together by a suddenly applied force which expels all overheated and contaminated metal from the weld. Hence a weld of strength equal to that of the parent material may be obtained.

With large sections preheating is often necessary, this being done by bringing the components into contact several times before welding. Post-heating is also sometimes carried out in flash welding machines in cases where excessive hardening occurs in the weld zone, as for high-carbon steels.

The sections at the joint on both components should be approximately equal in area, at least within 15 per cent, and the section at the joint should be uniform on each component for a minimum distance of one and a half times the amount of material to be lost from each component due to flashing and upset. Values for the allowances to be made for material losses due to flashing and upset when welding mild-steel round bars, flat strip or tube without preheating are available from published graphs and tables. Examples of good and bad joint designs are given in Fig. 5.

Although flash welding is used mainly for making butt joints in steel, it can be used to join most metals, including certain combinations for dissimilar metals.

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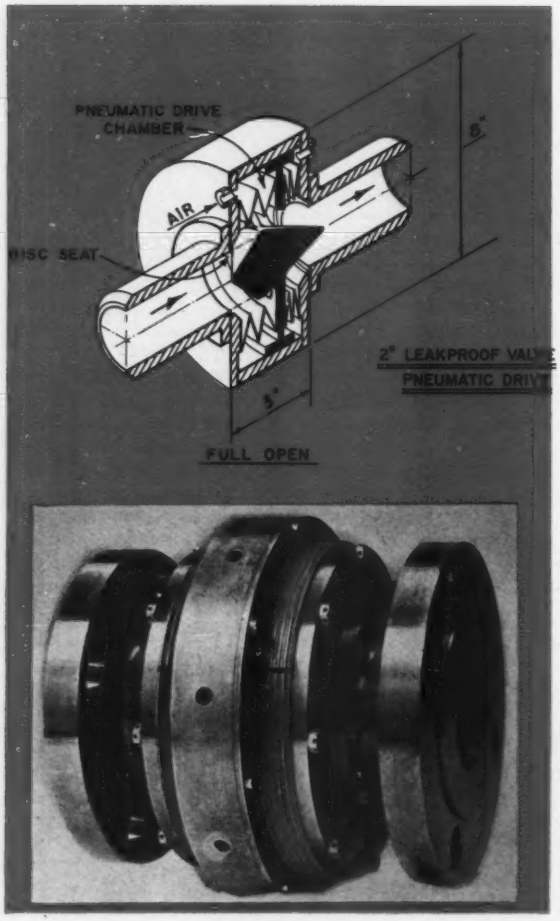
NEW IDEAS IN DESIGN

Outstanding products in current manufacture



Leakproof Valve for Hazardous Service

FOR handling radioactive and toxic fluids, Singmaster & Breyer, of New York, have developed a type of valve which is claimed to be leakproof.

The diagrammatic sectional view shows the working principle of the pneumatically-operated version. A central double-ended cone of streamlined form is held with its centre line coaxial with the inlet and outlet ports of the valve by a plunger which slides in the cylindrical body of the valve. The spaces between the legs of the spider, which hold the central cone at the centre of the plunger, allow fluid to pass when one end of the cone is not seated against the inlet port.

To each side of the plunger are fitted bellows which are attached to the inside faces of the ends of the valve body. It will be seen that with this form of construction it is possible to operate the central conical valve plunger without moving parts between the fluid chamber and the atmosphere. The photograph shows the mechanically-operated version.

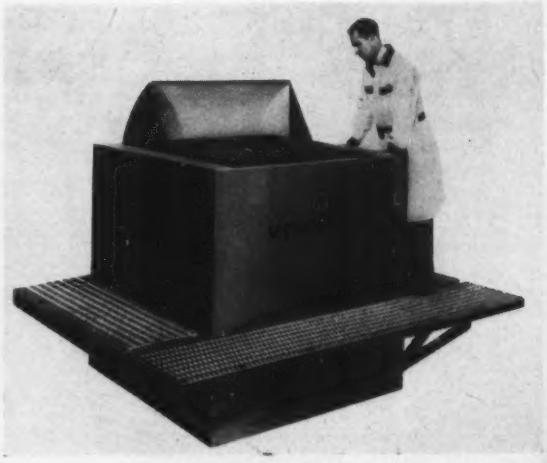
It is claimed that the valve is suitable for either tight shut-off or automatic throttling of gases and liquids, and that there is a negligible pressure drop across the closure disc. The internal parts can be made of any weldable corrosion-resistant material, while externals may be of conventional brass or steel. Limits of design working temperature are −5 to +820 deg. C., and design working pressures range from 0·005 microns vacuum to 150 p.s.i. in smaller sizes, and 30 p.s.i. in sizes up to 72 in. in dia. For 2-6 in. sizes the operation may be either by compressed air or mechanical means. For 6-12-in. sizes operation is by mechanical gear drive. Larger valves, which require hydraulic drive or synchronised motors, must be engineered for specific applications.

The valve was evolved from experience gained by the manufacturers in handling substances such as fluorine and uranium hexafluoride in various projects.

New Barrelling Machine Uses Vibratory Action

BY using a vibratory motion in place of the rotary action of the conventional-type barrel-finishing machine, Roto-Finish Ltd. claim that their new range of machines is superior to the older type of machine in several important respects. Faster and better descaling, deburring, radiusing, blending, smoothing and cutting down, bright honing and colouring are said to be possible, the new machines being six times faster than the rotary barrel.

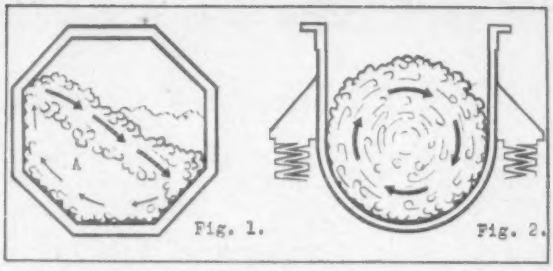
The reason given for this improved performance is that in conventional barrelling the abrasive action takes place in a sliding zone several inches deep which extends the width of the rotating cylinder (see Fig. 1). Beneath the zone, little or no relative motion takes place between the components and the processing media, the mass being carried around in a position of repose until the point is reached where it commences to slide. Thus very little work is accomplished in zone A. With the new vibratory system the container holding the mass is subjected to a three-way vibration which produces an overall rotary motion of the whole mass (see Fig. 2) and, at the same time, movement



of the individual chips in random directions. As the movement zone extends throughout the entire mass, work is accomplished much more rapidly.

Internal surfaces are treated as rapidly and as effectively as external surfaces, whereas in the rotary type of machine the amount of work that could be done on internal surfaces was severely limited. The vibratory system. however, enables the abrasive chips to move in three directions, and so be caused to flow through cavities at the same rate as over external surfaces.

Larger work loads relative to capacity can be accommodated in the new-type machines. This is due to a number of factors, the main one being that, as less impingement is caused, fewer chips are necessary for cushioning purposes. Thus a greater work load can be accommodated per overall cubic capacity of a machine. It is also claimed that the system is intrinsically more adaptable and flexible. Continuous flow processing, in which the parts emerge at the same speed at which they enter, can be arranged without difficulty.



The photograph shows a 7 cu. ft. capacity Vibratron. It is one of four machines with capacities from 1-7 cu. ft. produced by the company's U.S. associates. Special machines suitable for European industries are being developed by Roto-Finish Ltd. in the U.K., which include a two-tank version claimed to have further advantages over the single-tank type.

A Compact In-line Hydro-pneumatic Cylinder

IN recent years a number of air-cylinder and dashpot systems have appeared on the market for the operation of existing hand-fed machines, such as bench drill presses, milling machines, capstan lathes, etc., as well as for machines developed for operation in this way.

For the Fortis in-line cylinder, a very compact unit recently introduced by Luke Anthony Ltd., a number of advantages are claimed:

1. Rapid approach over any desired travel.
2. Feed rate infinitely variable or fixed, with rapid return.
3. Automatic control for any combination of movements in either direction.

The sectional drawing below shows the working principle. If the piston rod (A) is considered as moving on the forward stroke in the direction of arrow (X), the operations are as follows:

Compressed air is supplied to port (B), filling chamber (C) and causing piston assembly (T) and all attached components to move forward. Simultaneously, free air is exhausted from chamber (D) through port (E). When the rod (A) moves forward, oil in chamber (F) becomes subject to pressure, the ports (G) are closed by the ball check valve (H), oil is forced to flow through the port (J), thus restricting the speed at which the rod (A) can move.

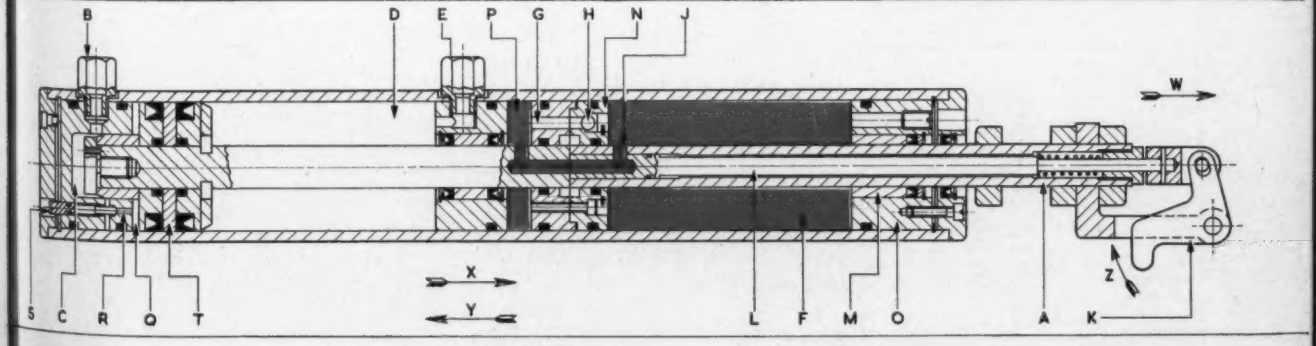
When the valve finger (K) is moved in the direction of arrow (Z), the flow control valve (L) is moved relative to rod (A) in the direction (W), thus restricting port (J), and reducing the speed of rod (A). If the finger (K) is moved to its maximum position in the direction (Z), the port (J) closes completely and all movement ceases. By providing a simple plate cam to engage with finger (K), it is possible to produce any combination of rapid traverse or infinitely variable feed.

If the rod (A) is allowed to continue its full stroke, the port (J) is cut off by the bush (M), thus providing a hydraulic cushion to prevent mechanical contact between the piston assembly (N) and the front cylinder head (O).

On the return stroke in direction of (Y), compressed air is supplied to port (E), exhausting free air from chamber (C) via port (B).

This action causes the ball check valves (H) to move off their seatings and opens ports (G), allowing oil to be rapidly displaced from chamber (F) to chamber (P), thus providing a fast return stroke. Since the return speed is high and the moving mass possibly several hundredweights, the piston is cushioned pneumatically at the conclusion of its stroke by trapping air in chamber (Q) and metering air through port (R) via restricter valve (S). Degree of cushioning is regulated by screwing restricter valve in to increase resistance and out to decrease resistance.

The Fortis cylinder, which operates on standard shop air-line pressure of 80 p.s.i., is available in bore sizes of 2¼-6 in. It is particularly suitable for use in confined spaces.



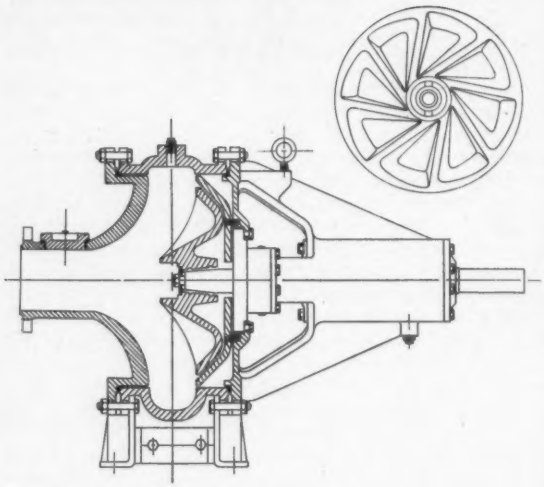
Torque Pump that Eliminates Conventional Impeller

A NEW pump of unusual design, the Wemco torque flow pump, was exhibited for the first time in this country by West's (Manchester) Ltd. at this year's Mining Machinery Exhibition.

The principle of the pump, patented by the Western Machinery Co., of San Francisco, ensures the unobstructed passage of any liquid/solid combination that will pass through the ancillary piping, thereby eliminating clogging.

The pump operates by creating a vortex effect, causing pulp in the main pump body to rotate, thus developing the suction and pressure heads necessary for pumping. This action is achieved by locating the impeller out of the main flow path so that the suction and discharge waterways become one continuous open passage. The solids are therefore drawn into the vortex by the swirling liquid and are discharged with a centrifugal sweep from the open chamber, seldom touching the impeller, so that friable and easily damaged solids can be pumped successfully as well as highly abrasive pulps. The design therefore avoids damage to solids being pumped and affords protection from excessive wear to the pump parts themselves.

Among the pulp materials which are being efficiently handled by the Wemco torque flow pump are ores, coal, cement, sand, gravel, tailings and froths, coal refuse, bilge, paper pulps, rags and sewage.



The pumps are available for capacities up to 2,500 imp. gal./min. and heads up to 120 ft.

A Ropebelt Conveyor Suspended on Cables

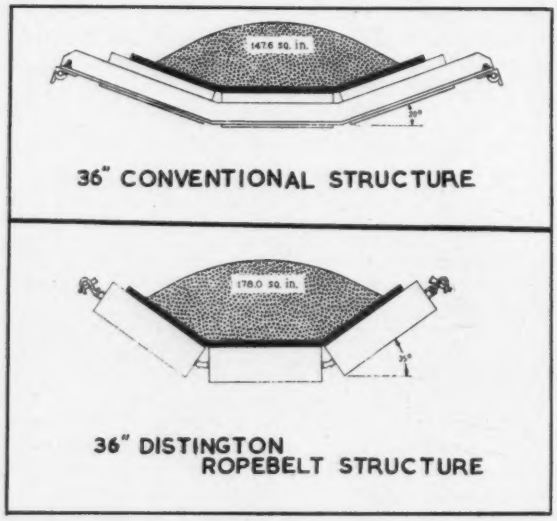
THE Distington-Goodman Ropebelt conveyor recently introduced is claimed to have a carrying capacity at least 20 per cent greater than that of conventional rigid or rope-framed conveyors.

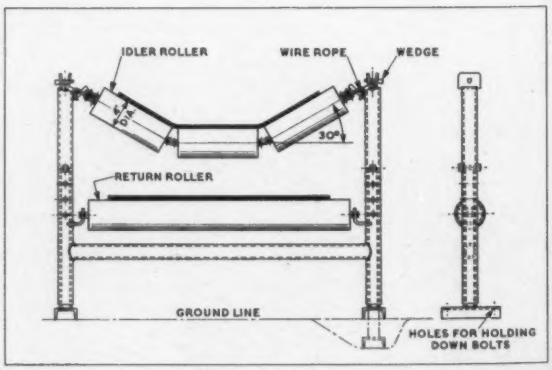
This is achieved by suspending the rollers, the shafts of which are flexibly connected by chain links, from two wire ropes. The wire ropes are held at intervals by welded tubular frames. As weight is imposed on the Ropebelt conveyor, the wire ropes flex inwards and downwards and at the same time each idler flexes. This combined action deepens the trough of the idler assembly, thereby increasing the carrying capacity.

A spreader is normally used half-way between rope supporting stands when four carrying idlers are installed between the stands. It helps to maintain spacing of the ropes and to prevent the centre idler roll from deflecting downwards to the point where it could interfere with the return belt. The spreaders hook on to the wire ropes and are anchored by steel wedges.

The wire rope is $\frac{5}{8}$-in. diameter and 6 × 19 ft. regular lay, improved plough steel with steel core. It is said to be easy to coil and handle.

The component parts of the system are few in number and are claimed to be easy to handle. Spacing of the idlers and rope-supporting stands can be varied to suit load requirements. In some instances, provided the load to be carried is not too great, it is possible to extend a conveyor without acquiring additional components, other than wire rope.





MAKING RESEARCH PROFITABLE TO INDUSTRY

An industrial consultant appeals for a fresh approach to research costs

by L. H. CALLENDAR, Ph.D., B.Sc., D.I.C., A.R.C.S., F.R.I.C., F.I.M.

INDUSTRIAL firms undertake research only for what they will get out of it. The new scientist from university or college seldom appreciates this, and if he is ever to become a successful director of industrial research, he cannot afford to waste time on insoluble problems.

This idea is new when applied to research, for most people think that science can quickly solve any problem; in fact, in the U.S.A. they seem to reckon that, if you bring enough research workers together, someone is bound to think of the right solution. Nothing could be more absurd; all the really important discoveries of science have been made by individuals, or by those controlling teams who have done the routine experiments under their direction or who happen to be brilliant men within teams and make a vital contribution which completes the solution of the problem. On the other hand, the chief effect of gathering a lot of people together is to obtain the lowest common measure of intelligence; from this nothing really original arises, because there is little or no opportunity for anything but superficial thinking, and people in the mass are always afraid of original ideas. Research committees are especially dangerous; they should be only for discussion and never allowed to make majority decisions.

An "insoluble problem" may be taken as one on which several people have already worked without success.

However, if a new technique for tackling the problem (such as the electron microscope which enables one to see smaller particles than ever before) has become available, then it may be worthwhile going into the matter again.

Thus, it will be seen that the most important function of a director of research is to select the problems he will undertake, refuse those which seem unlikely to provide a solution in a reasonably short time, and curtail those which show no promise of results in proportion to their intrinsic importance.

A director of one of the largest and most successful industrial research organisations has said that four out of five problems which come into the department are insoluble; they are sent in by outside contacts of the industrial management, who may not appreciate what is practical in either research or manufacture.

An example of this was a wonderful new Russian battery called a "fuel or gas cell" which appeared in the Press as if it was an entirely new idea and caused a considerable commotion in the industry. However, this idea was first put forward about 120 years ago in Britain and was developed by Ludwig Mond, and more recently by Bacon, to give a much higher output than that claimed for the Russian cell which (more recent investigation has shown) was only for a student's thesis.

The major difficulty that the discovery and development of new scientific ideas has to meet in industry is that the final decision as to what shall be done is usually made at the semi-technical or non-technical levels of management; this is because such people control the finance necessary for any such work to be put in motion. New projects may come into them first through sales departments or outside agencies and, lacking sufficient technical knowledge or adequate advice, they frequently insist on going ahead for other than technical reasons. That is the root of the difficulty—a large amount of money is wasted at high level on useless projects to which there is no profitable conclusion anyhow, and some projects based on knowledge and put up from below are rejected from lack of funds wasted on useless projects.

The correct procedure for these top directors without special knowledge would seem to be to give their scientific chief the status of director, and, to counterbalance the usual majority of non-scientific directors give him equal status with the general managing director, at least in industries where technology is of major importance. The scientific director will then naturally decide what research will be done with financial limits, and have the power to allocate funds to problems he is confident will prove soluble. This will have an added advantage in the economic use of the usually short-staffed technical side of a business. If his judgment in the long run is shown to be unsound, then the directors can replace him.

There are, of course, some problems which appear at first sight to be insoluble, but which, from the national point of view, must be solved. These must be tackled by Government institutions supplied with funds according to policy. Unfortunately, in Government institutions, owing to lack of competition (other than in war), the waste of time on useless insoluble problems is generally much greater than in industry, while committees tend to water down responsibility and shelve decisions. A former superintendent said recently: "In my work there are now five times as many committees as there were before the war, no more staff, more talking and less research completed."

The attitude that is necessary for industry is very different from that towards academic research in universities. For the latter, a great part of the time is concerned with training students to do research, and it is really not essential for them to solve the problems, provided they have learned something about research techniques. In industry, on the other hand, as we have seen, all operations must be controlled by time and money and nothing should be undertaken unless there is more than a fifty-fifty chance that it will pay for itself in a reasonable time.

The key question is: "What is a reasonable time?" Here we can get some help in a published article from I.C.I. Ltd.[1] on their research organisation. They say that, at the moment, for I.C.I. as a whole, the cost of researches on the average is being returned in 3¼ years by the profits arising from the implemented researches (this includes unsuccessful researches which, of course, yield no profit).

The managing director and the research manager of any organisation have here the answer to the major problem that has faced them for years in regard to research and development. How long will it take? How much will it cost? It is clear that research and development as a whole must be planned (never rigid, but a flexible outline modifying details as the trend of results indicate) on a basis of three to four years, both as regards finance, staff, apparatus, probable market, etc., with about 25 per cent for eventualities. They must not expect quick results, for such are likely to be unsound, or lucky or from a very simple problem. They can at least avoid many commercial problems over-running the three to four years' average by ruthlessly cutting out, at the start, the majority of insoluble problems.

No statements made in this article necessarily apply to any organisations to which the author has been or may be acting as consultant.

REFERENCE
1. *Metal Industry*, July 5, 1957, p. 7.

designer's notebook

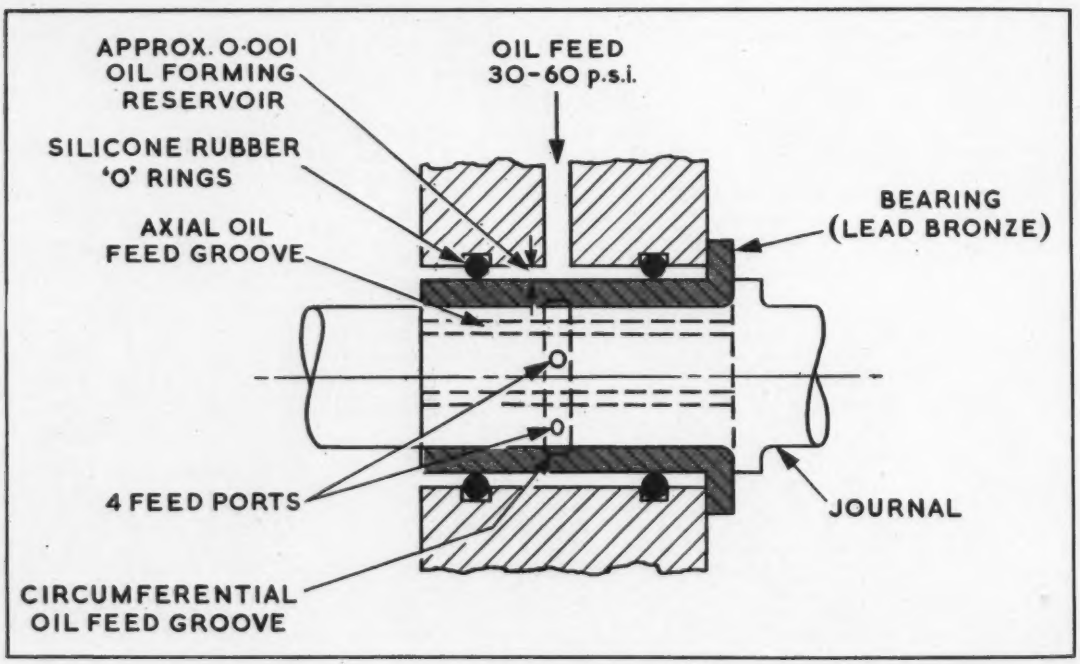
Flexibly Mounted Bearings for High-speed Applications

SHAFTS revolving at speeds of about 100,000 r.p.m. present a difficult problem to the bearing designer. While static and dynamic balancing can be effected to a fine degree, it is inevitable that excitation and superimposed vibration are set up which impart high localised stresses on the shaft and its bearings, leading to early failure.

One method of overcoming this difficulty is to accommodate the amplitudes on the shaft within the bearings, and this has been successfully carried out in the C.A.V. Turbo Charger developed by the B.S.A. Group.

In this patented design each of the two bearings is housed in two O-rings of silicone rubber, the annular space between them serving as a pressurised oil reservoir. One of the bearings is shown (in colour) in the sectional sketch. The oil is fed to a circumferential groove through four ports which maintain a constant hydrodynamic pressure between the bearing and the shaft, since peak loadings may occur at any radial point. Axial grooves spread the oil to the extremities of the bearings. As the exhaust-driven turbine runs at a considerably higher temperature than the coaxial blower, it was found necessary to provide a larger number of oil ports for the bearings on that side of the shaft.

This design enables a standard lead-bronze bearing material to be used in conjunction with a journal steel shaft, and shaft clearances may be made a little larger than normal.



Quick-acting Pilot Valve

THE purpose of this mechanism is to provide a pilot valve quicker in action than those hitherto available, particularly in those applications where hydraulic or pneumatic apparatus is controlled by electronic devices.

In known pilot valves the sequence of operations is:

1. The operating signal is applied to the first stage, usually a solenoid.
2. The second stage, a small valve, is operated directly by the first stage and admits fluid under pressure to the servo cylinder.
3. The servo piston moves under the influence of the fluid and operates the main valve.

In the present invention (for which a patent application has been made) the sequence is:

1. The operating signal is applied to the first stage, which may be an electromagnet or other device.
2. The first stage releases a detent, which frees the servo-piston rod.
3. The servo piston, already under pressure from fluid admitted by a fully-open pilot valve, accelerates rapidly and operates the main valve.
4. The servo-piston rod is locked in its new position by a detent, and at the same time the pilot valve changes over to admit fluid to the servo cylinder, ready to move it back to its original position as soon as the detent is again operated.

In known pilot valves the solenoid must be powerful enough to operate the pilot against friction and, in many

cases, against hydrodynamic forces within the valve. In all but the smallest valves, the solenoids demand more current than can be supplied direct from the output of the electronic circuit, and the inductance of these comparatively large solenoids introduces a time lag. When, as is usual, the solenoid is operated by a contactor or other relay mechanism, a further time lag is introduced. While the pilot valve is opening the fluid is throttled, so the servo piston accelerates comparatively slowly until the pilot is fully open.

In the present invention the pilot valve operates *after* the servo, and then waits fully open ready for the next operation. The detent may, according to the dictates of cost and the demands of the application, be anything from a simple ball interlock to a hair-trigger mechanism, and even in its crudest form it will require less power and will operate in a shorter time than would a pilot valve, and the servo piston will be subject to maximum acceleration the instant it is released by the detent.

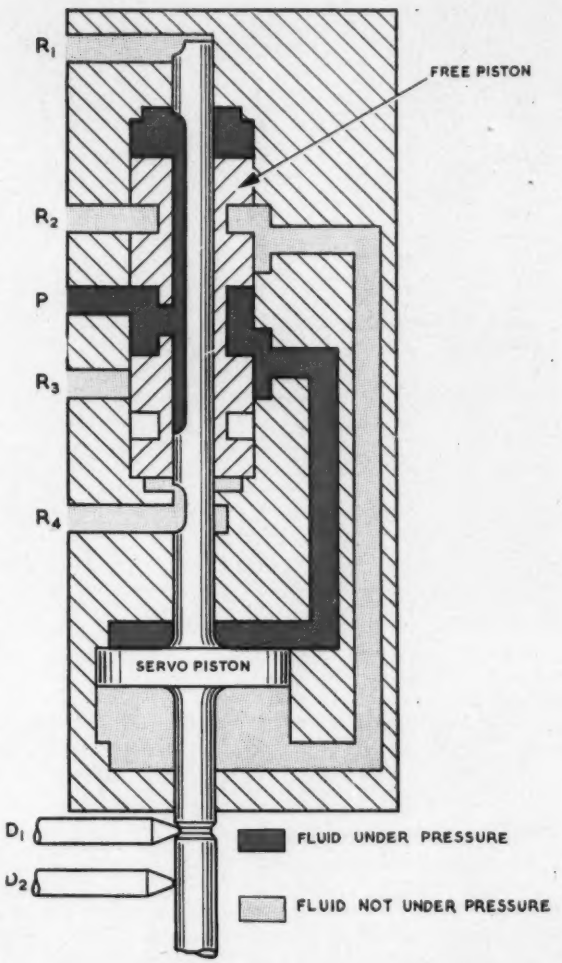
In the illustration (right), showing fluid under pressure in dark colour, the pilot valve comprises a ported cylinder in which a piston is free to move under fluid pressure applied at either end. Port P is connected to the pressure side of the fluid system and the ports R1 to 4 (which would, in practice, have a common external connection) lead to the reservoir.

The rod of the servo piston extends into the pilot-valve cylinder and passes through a bore in the free piston. This rod is furnished with flats machined on one side as shown, and a number of holes (only one of which is shown) communicate between the bore of the piston and the central groove in its outer surface. The piston rod extends in the other direction to operate any required type of linear two-position valve, and is locked by one or other of the two detents D1 and D2.

The piston is shown locked in its upper position, and it will be seen that its rod closes port R1, opens port R4 and admits pressure to the top of the free piston, which has therefore moved to the bottom of its cylinder. In this position it opens the top of the servo cylinder to pressure and the bottom to reservoir, so the servo piston is urged downwards by the full fluid pressure.

When the magnet frees detent D1 the servo piston will at once thrust downwards under the pressure of the fluid, which passes through the fully-open pilot valve, and operate the main valve. As it reaches the end of its travel it will be locked by detent D2, and the upper extension of its rod will open port R1, close port R4, and admit pressure to the lower end of the free piston, which will instantly fly to the top of its cylinder. In this position the free piston will open the top of the servo cylinder to port R3 and the bottom to pressure, urging it upwards ready for instant action when the detent D2 is released.

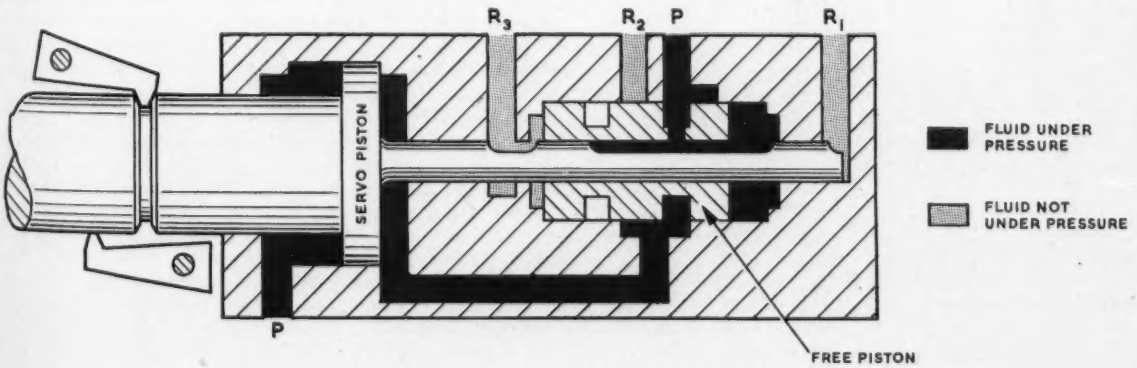
The acceleration of the free piston may be controlled by restricting ports R1 and R4, to match its movement to that of the main servo piston and ensure the correct functioning of the detents. The detents may be operated by two electromagnets or one magnet with an on-off action, as required.



The basic principle of this device may, of course, be applied in several ways according to requirements. The version of the valve shown has been chosen for simplicity of explanation, but engineers will appreciate that a more compact version, using a differential piston, could be developed, as shown in the drawing below.

The invention is applicable to other two-position linear mechanisms besides valves.

S. Z. Milledge



OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Concrete Machine Tools

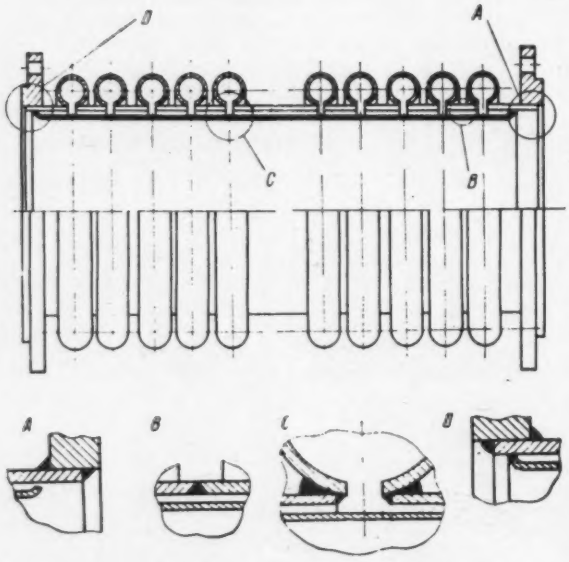
Chinese engineers have recently made extensive use of reinforced concrete for various parts of machine tools. Not only does this result in considerable economy of metal, but it is claimed that weight and cost reductions can be made.

Although one of the main objects has been to enable large machine tools to be made in districts where there are inadequate foundry and heavy machining facilities, the use of concrete would appear to have useful applications for very large machines required in small numbers or for one-off designs and prototypes. Among items which have been successfully manufactured from reinforced concrete are the bed and column of a vertical milling machine, stands for small drilling machines and the bed and vertical columns of a 10-ft.-dia. vertical lathe. Metal slide and guides can be sunk into the concrete to provide working faces. The use of concrete has enabled new designs to be put into production with great speed; an example is cited of a horizontal boring machine (2-ft.-dia. spindle) which was designed by a team of five men in twenty days and production was started only thirty-five days after design work was begun.

Expansion Fittings in Pipelines

An interesting Russian design of an expanding length of tube is shown in the illustration. This design (reported in the journal, *Energomashinostroyeniye*) is suitable for large-diameter pipelines where it replaces bellows, and would appear to have the advantage that it can be manufactured without highly specialised machinery.

The unit shown was developed by one of the Russian turbine-manufacturing plants and is intended for the supply of gas at a temperature of up to 600 deg. C. All the components of the welding assembly are made of stainless steel.



Longitudinal section of the Soviet expansion tube.

In making the assembly, tubes are machine bent and each tubular ring is welded from two parts one of which subtends an angle of 260 deg. and the other an angle of 100 deg. The ring is welded to two short lengths of casing before the slot is cut on the inside. The short lengths of casing are then butt welded to each other.

Nine per cent Nickel Alloy Steel

A recent introduction in the field of materials that can be used for low-temperature pressure vessels is low carbon 9 per cent nickel alloy steel. It is a ferritic steel and said to be stronger, tougher and less expensive than other metals at present used for handling liquefied gases. In many applications it is expected to replace both stainless steel and aluminium because of its lower cost. It can be either hot or cold formed by the usual processes.

International Nickel Co. states that under impact tests it was found that fractures did not propagate at temperature down to −200 deg. C. compared with a figure of −20 deg. C. for the highest grade pressure vessel carbon steel. The new alloy is said to exhibit exceptionally good plastic fatigue resistance and this superiority is said to be retained at low cycle fatigue lives. It does not experience the usual loss in plastic fatigue at high strains characteristic of high strength steels. Welding is said to present no difficulties and any increase in hardness or loss of notch impact strength is reported to be overcome by stress relieving at 570 deg. C.

New Electron Source

A development which may well affect the present trend for transistors to replace electronic valves has been announced by the Westinghouse Electric Corp. in the U.S.A. Conventional valves require an electron source consisting of a coated wire or cathode which must be heated to a high temperature, and this not only demands the provision of considerable electric power, but gives rise to problems of heat dissipation. The new method of electron emission from semiconductors may eliminate this inefficient process by replacing the cathode with a minute crystal of silicon carbide which yields electrons instantly when a small electric voltage is applied across it. The crystal consumes a negligible amount of power and, being small, opens up new possibilities for miniaturisation in valve design.

Fibre-reinforced Lead

A further step in the search for new composite metals (as distinct from alloys) is the work sponsored by the U.S. Lead Industries Association in developing methods of producing self-supporting lead products by reinforcement with metal fibre mats. Composites produced by immersing phosphor-bronze mats into molten lead alloys have exhibited tensile strengths which are approximately equal to the sum of the strengths of the component parts. For instance, a 90/10 lead-tin alloy having a tensile strength of 4,900 p.s.i. combined with a phosphor-bronze mat of 1,480

p.s.i. gives a composite having a strength of 6,400 p.s.i. This is less than the theoretical value, but it is believed that incomplete bonding between the fibre and matrix phases and also the formation of a brittle inter-metallic phase may be responsible for limiting the strength.

These factors also limit the amount of cold working which can be carried out on the composite, although in some cases a reduction of 75 per cent has been possible before cracking. Improved processing techniques to reduce the brittle phases and to increase the bond strength are at present under investigation and composites incorporating steel fibres are also being made.

Polyamide Plastics for Textile Machinery

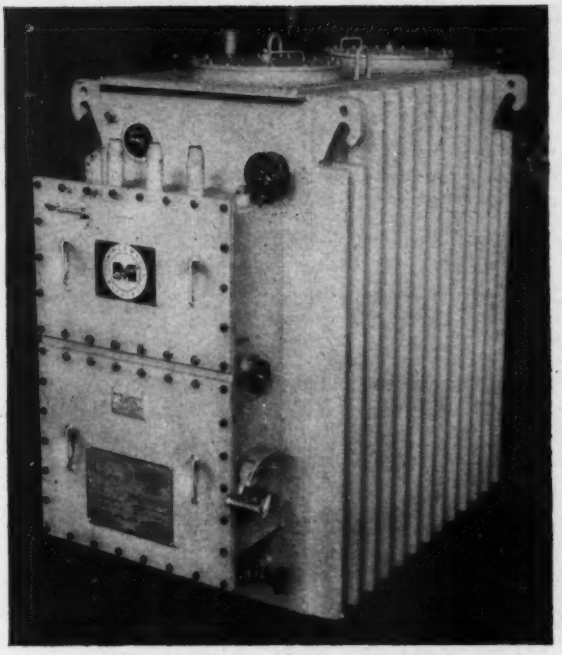
Shuttles on textile looms have formerly been manufactured from special hard wood and the production cost is high, while the shuttle life has been limited. Initial attempts to use polyamide plastics were not satisfactory owing to cracking caused by internal stresses which developed during production, and because of distortion caused by mechanical forces on the shuttle walls by the race board springs.

It is now reported that these difficulties have been overcome in Czechoslovakia by paying special attention to the injection moulding process, by eliminating pigments and by finishing treatments. Much depends also on the correct removal of internal stresses. It is claimed that polyamide shuttles are cheap to produce, give long service and have reduced loom stoppages due to shuttle trouble to a low level never before reached with wooden shuttles.

Other accessories, such as a new type of relieved cop with a device regulating the tension of the weft yarn, have similarly been developed using polyamides to replace metals.

Aluminium In Electrical Equipment

Two new applications demonstrate the increasing penetration of aluminium into the electrical industry, one of the largest potential markets for aluminium. One is a prototype, experimental electrical distribution transformer which, except for the core and insulation, is made entirely of aluminium. This transformer is designed to step the relatively high voltages of utility lines down to the usual 110-220 volts used in the American home. Aluminium foil strip conductors are used for the windings of the 25-kVA. transformer. Aluminium structural members support the coil in the aluminium outer tank.



This 500 kVA. transformer makes unprecedented use of aluminium.

Shown here is a 6061 aluminium transformer case made for a 500-kVA. network transformer. Use of aluminium for the tank is expected to completely eliminate corrosion and maintenance problems in severe industrial and coastal environments. The integral corrugations used on the sides of the tank replace the usual transformer radiator tubes. These corrugations eliminate side welds and other potential sources of leakage and maintenance problems.

WIDE RANGE OF INTEREST AT BRITISH DESIGN CONFERENCE

MORE details are now available of the papers to be given at the first ENGINEERING MATERIALS AND DESIGN technical conference that will be held at Earls Court from February 22-26.

The following are the principal subjects that will be dealt with, together with the speakers who have agreed to participate:

Alloy Steels
H. C. Child, B.Sc. (Glasgow) (Jessop-Saville Ltd.).

Stainless Steels
J. I. Morley, A.Met. (Sheffield), F.I.M. (Firth-Vickers Stainless Steels Ltd.).

Beryllium
A. J. Martin, Ph.D., B.Sc. (U.K.A.E.A.).

Reinforced Plastics
A. W. Thompson, B.Sc., A.F.R.Ae.S. (Bristol Aircraft Ltd.).

Rubber in Engineering
A. N. Gent, Ph.D., A.Inst.P., A.I.R.I. (British Rubber Producers' Research Association).

Pumps for the Processing Industries
J. O. S. MacDonald, B.Sc., A.R.I.C., A.M.I.Chem.E. (Editor, *British Chemical Engineering*).

Standards in Design
R. K. Whitehead (English Electric Co. Ltd.).

Centrifugal Castings
I. L. Gwynn, L.I.M., A.C.T.C. (P.I. Castings (Altrincham) Ltd.).

Seals
E. T. Jagger, B.Sc. Eng., Ph.D., (Geo. Angus & Co.)

Plastics for High Temperature
V. E. Yarsley, M.Sc., D.Sc. (Tech.), F.R.I.C., F.P.I., M.I.Chem.E., Hon.A.C.T. (Birmingham) (Yarsley Research Laboratories Ltd.).

Safety in Design
B. Shackel, M.A. (E.M.I. Electronics Ltd.).

Design Trends in Germany
J. Shapiro, Dipl. Ing., A.M.I.Mech.E., A.F.R.Ae.S.

Appearance Design
R. M. S. Kay, B.Sc. Tech., D.A.A., F.R.S.A. (Metropolitan-Vickers Electrical Co. Ltd.).
H. A. Nieboer (consultant).

Photoelasticity in Design
C. Snell, M.Sc. (University College,, London).

High-pressure Hydraulics
D. E. Turnbull, Ph.D., B.Sc. (Eng.) (British Hydromechanics Research Association).

Among other subjects to be included in the conference for discussion are: magnesium alloys; powder metallurgy; castings; and fluid power.

SELECTION OF BALL AND ROLLER BEARINGS

This article, the second on the subject of bearing materials and units, surveys the immense range of ball and roller bearing types available, and shows how they should be used

by A. J. MARLES, B.Sc., A.C.G.I., A.M.I.Mech.E. *

TO obtain satisfactory and efficient service from a bearing, it is essential to select the correct type for the duty it is required to perform. Having made this choice, the user must then select a suitable size, mount it correctly, give it protection from foreign matter, lubricate it and give it proper maintenance during service. If all these points are carried out, then no trouble will result and the bearing will function satisfactorily until it fails through fatigue. It is true to say that few bearings, having been correctly selected, mounted, lubricated and maintained, fail through premature fatigue.

Although from the design aspect it is always advisable to seek advice from manufacturers at an early stage, the user should have some knowledge of the advantages and disadvantages of the various types.

To simplify this study, a division has been made into the following four basic types:

1. Radial ball bearings.
2. Radial roller bearings.
3. Thrust ball bearings.
4. Thrust roller bearings.

It is not possible to make straightforward and clear-cut divisions, since some types can be classified under two basic headings. In addition, it is not possible or desirable to cover all the variations in an article of this nature, and comments have been confined to the most widely used ones in order to avoid excessive complication. An omission should not be taken as an implication that a bearing is not well designed or could necessarily be replaced by one described, for many of these bearings are essential to the satisfactory operation of some machines.

For the same boundary dimensions roller bearings have a higher load rating than ball bearings, and so they are useful when loads are heavy, and when the possibility of momentary overloads exists. Broadly speaking, the maximum operating speeds for the two types are similar for identical operating conditions, although with some types of roller bearing the lubrication is more critical than with ball bearings. This is because of the large areas of sliding contact between the rollers and guiding flanges. In general, the rigid single-row ball journal bearing is the cheapest and most widely used, particularly when a shaft has to be supported in both radial and axial directions.

Radial Ball Bearings

RIGID SINGLE-ROW BALL JOURNAL BEARINGS—These types can be subdivided; first, where the shoulders of the inner and outer races are continuous (Fig. 1 (a)) and, second, when there are notches or filling slots in both races (Fig. 1 (b)). In the first type the balls are assembled by eccentric displacement of one race relative to the other, and the last ball is then assembled by elastic distortion of the outer race. In certain instances elastic distortion may not be necessary. With the filling slot type, as many balls as possible are assembled by eccentric displacement, and the remainder are inserted through these slots. There is a small amount of interference between the balls and the slots, so pressure and a limited elastic distortion of the outer race are necessary. The notched type of construction enables a greater number of balls to be assembled, and in fact it is possible to fill all the pitch circle circumference; in this case no cage is fitted and the bearing is frequently referred to as "full type" or "cageless". The use of a cage, whose main function is to space the balls correctly, means that higher speeds of operation are possible, since the points of rubbing contact between adjacent balls are eliminated. Full-type bearings are not satisfactory for high-speed operation because rubbing speeds between adjacent rolling elements are high, and this leads to high heat generation.

The notchless ball journal bearing is the most popular type of bearing in use. The fact that the radii of the tracks are only slightly greater than the ball radius, i.e., with close track conformity, results in a bearing having a high load-carrying capacity. The construction of the bearing, as can be seen from Fig. 1 (a), enables it to take radial load and/or thrust load from either direction. Its ability to take thrust load is very dependent upon the angle of contact between the balls and tracks, this in itself being largely dependent upon the diametral clearance in the bearing. For bearings of this type that are to take thrust load, it is advisable to use the slacker fit (i.e., D.C.3 or "000").

The diametral clearance, frequently referred to as "fit" of a bearing, is the total internal clearance between the rolling elements and the tracks when measured in a radial direction. It is, in fact, the difference between the diameter of the outer track and the sum of the inner track diameter, plus twice the rolling element diameter.

Journal bearings are available with different grades of diametral clearance, and the selection of the correct grade is dependent upon the need to have the correct clearance in the bearing when operating. The main factors to be considered are the shaft and housing fits, the type of loading, the expected temperature differential across the bearing and the degree of rigidity required. It is recommended that users consult the bearing manufacturers about the grade most suitable for their particular operating conditions, and the grade should then be specified when ordering the bearings.

It is standard British practice to identify the three normal diametral clearances by means of faint circles on the stamped face of one race. These can range from "0", signifying minimum clearance and known as D.C.1 or "one dot", to "000"' slack fit, known as D.C.3 or "three dot".

A ball journal bearing is very suitable for high-speed operation, but, for such applications, by the use of special

* *Assistant technical manager, Ransome & Marles Bearing Co. Ltd.*

cage designs and materials, etc., it is possible to raise the maximum possible operating speed of the more commonly used bearings.

This bearing is not self-aligning, but a very limited amount of shaft deflection and initial misalignment can be accommodated if a slack internal fit is used, since this does mean a less rigid bearing.

The major difference between the notched and notchless designs is that the former has the higher radial load-carrying capacity. This depends upon the number of balls that are assembled, since the capacity is proportional to the number of balls to the power of two-thirds. (It should be remembered that load-carrying capacity increases with increase of rolling element diameter, and this has a greater effect than the number of rolling elements.) It is important to note that the notched construction is less suitable than the notchless type for axial loads, and from this aspect it must be derated to some extent. In fact, it is not to be recommended for carrying high thrust load alone, since the balls will then be rolling over the edge of the notches. Due to the presence of these notches, the maximum operating speeds are lower than the notchless type, even when a cage is fitted.

ANGULAR CONTACT SINGLE-ROW BALL BEARINGS—The construction of these types (Fig. 1 (c)) enables a greater ball complement to be assembled than in the notchless rigid types, and they are inseparable. It is most important for the user to note that the outer races of these bearings must not be stripped from the inner race or the bearing will be damaged. Usually, the outer is thermally expanded to allow the balls to be assembled through the counterbore, but this means that they should not be subjected to radial loads alone due to the possibility of damage by running on this counterbore.

The bearing is designed to run with an angle of contact between the balls and tracks; this angle varies from one manufacturer to another and also for the application under consideration, since the thrust capacity increases with the contact angle.

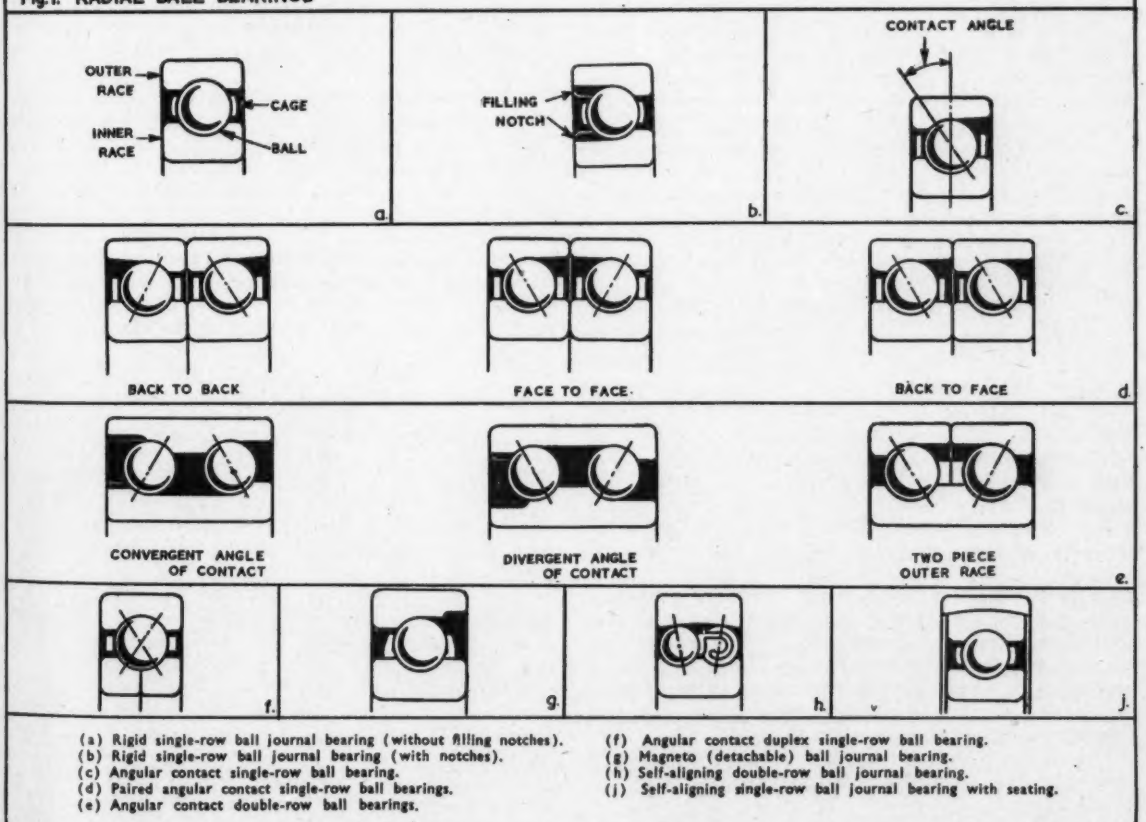
Due to their construction, these types have a higher thrust capacity than the rigid types and also they are capable of high-speed operation. They are also used where both radial and thrust loads in one direction occur, and the latter forms the greater part of the total load.

It is essential for these bearings to be mounted the correct way, i.e., with the load taken against the deep-side of the track or groove in the outer race. Some makers stamp the word "thrust" on this face of the outer race to assist the user.

In using the bearing it is essential to mount another bearing with it to take the induced reverse thrust load. Even when a pure radial load is applied to this bearing, the contact angle gives rise to a resultant thrust load; and an equivalent thrust force in the opposite direction is essential to prevent axial displacement of the two races. This is frequently obtained by mounting a similar bearing the opposite way round. In a mounting of this type it is essential to adjust the bearings axially so that the free end play is removed; if this is not carried out, the balls may track on the edge of the counterbore, with the probability of premature failure. If the bearings are overadjusted, i.e., clamped up too tight axially, preloading will be caused and this could again result in premature failure. This is a common problem.

When extreme rigidity is required under all loading conditions, angular contact single-row ball bearings are often mounted in pairs. This is particularly so in the machine tool industry. Fig. 1 (d) shows the three methods

Fig. 1. RADIAL BALL BEARINGS



(a) Rigid single-row ball journal bearing (without filling notches).
(b) Rigid single-row ball journal bearing (with notches).
(c) Angular contact single-row ball bearing.
(d) Paired angular contact single-row ball bearings.
(e) Angular contact double-row ball bearings.
(f) Angular contact duplex single-row ball bearing.
(g) Magneto (detachable) ball journal bearing.
(h) Self-aligning double-row ball journal bearing.
(j) Self-aligning single-row ball journal bearing with seating.

of pairing the bearings. These bearings are specially manufactured with definite offsets or "stick-outs" of the race rings. The offset or "stick-out" is a slight difference in width of the inner and outer races and is only a few thousandths of an inch in the maximum condition. When these bearings are clamped tight to remove this offset a known amount of preload is established in the bearings. Pairing of bearings ordered individually should never be attempted, and having ordered a pair for one of the methods of mounting they should not be mounted another way without expert advice.

The back-to-back and face-to-face mountings are designed to carry heavy combined radial and thrust loads, with the latter in either direction.

The back-to-face or tandem mounting is used for combined duty where there is a heavy thrust load in one direction: the bearings are preloaded through another opposing bearing to maintain the required radial and axial rigidity.

ANGULAR CONTACT DUPLEX SINGLE-ROW BALL BEARINGS—The construction of these bearings is shown in Fig. 1 (f), the alternative being to split the outer race radially. A large complement of balls can be assembled with either construction. The track formation used results in a very high thrust capacity. The bearing can carry thrust in either direction with only a limited axial shaft movement under directional change of the load.

The balls are retained by a cage and it is essential that the parts of the bearings are not mixed as they are not interchangeable; most makers serial mark the parts to obviate the risk of this. It is essential for the split race to be clamped tight in the mounting.

To ensure correct tracking of the balls, the thrust load must form at least 75 per cent of the total load.

There are two variations of this bearing, the type required depending on the loading conditions in the application. The more generally used one is made about 0·003-0·006 in. under nominal size on the outside diameter; this means that if the housing is made to suit a nominal bearing outside diameter, the bearing is clear in the housing. As a result of this, it is relieved of radial load (provided that another bearing is used to take this) and can thus carry the very high thrust loads for which it is designed. In the second variation, the bearing is made to the nominal outside diameter, and so is not relieved in a standard housing bore; it is thus able to take radial as well as axial loads, provided that the ratio of these satisfies the condition previously stated. Manufacturers' catalogues should be consulted for full details of these two variations.

The main advantage of this bearing is its ability to carry very high thrust loads and operate at high speeds.

MAGNETO (DETACHABLE) BALL JOURNAL BEARINGS—These are variations of the angular contact single-row ball bearing and the construction is shown in Fig. 1 (g). They are normally only available in the smaller metric sizes. They differ from the previous type in that they are separable; the counterbore in the outer race is cylindrical and tangential to the groove or track. For this reason, the balls are only retained in the cage and the bearings are made to interchangeable limits. The groove or track diameter of the outer race is closely controlled so that the outer races can be changed from one bearing to another without affecting the functioning of the bearing. The bearing can thus be mounted in two parts, which is a useful feature when large quantities are involved, particularly since the outer races are interchangeable with other bearings of the same size.

Due to the cylindrical counterbore, radial shaft support cannot be obtained if the bearing is mounted with axial play present.

Apart from the above, the properties of this type are the same as the angular contact single-row ball bearing.

ANGULAR CONTACT DOUBLE-ROW BALL BEARINGS—Broadly speaking, there are three variations of these types illustrated in Fig. 1 (e), but each is basically a compounded pair of the single-row types. They are normally supplied with a limited amount of axial play or with preload and cannot be adjusted by the user.

All are assembled with large ball complements and are capable of carrying high thrust loads in both directions, as well as radial load. Due to load distribution within the bearing, the load-carrying capacity is dependent upon the ratio of radial to thrust load applied.

Two of the types shown in Fig. 1 (e) are manufactured with filling slots on one side of both races, whereas the third one shown has no filling slots, but a split outer race with each half similar to the angular contact single-row ball bearing.

The convergent-angle type illustrated is manufactured with a smaller distance between the track or groove centres of the inner than the outer race, so the contact angles intersect outside the bearing. The opposite is the case with the divergent-angle type.

With the two-piece outer race type shown, it is essential to clamp both the inner and outer races axially. With this construction and where both radial and unidirectional axial loads occur, it is possible to increase the bearing capacity by relieving the housing bore over one half outer. This enables this row of balls to carry the thrust load only and the other row to carry the radial load and induced thrust load.

SELF-ALIGNING DOUBLE-ROW BALL JOURNAL BEARINGS—These (Fig. 1 (h) are designed with a spherical outer track which enables them to align truly and without additional loading to the bearing. The main advantages are to accommodate misalignment errors and shaft deflection. The shape of the outer track results in low capacity due to the poor conformity. These bearings are not recommended for carrying appreciable thrust loads, due to the tendency of the balls to wedge in the relatively flat track of the outer race.

It also reduces the ability to carry shock loads, and the performance in the presence of vibration is not good. These bearings are not recommended for high-speed duty.

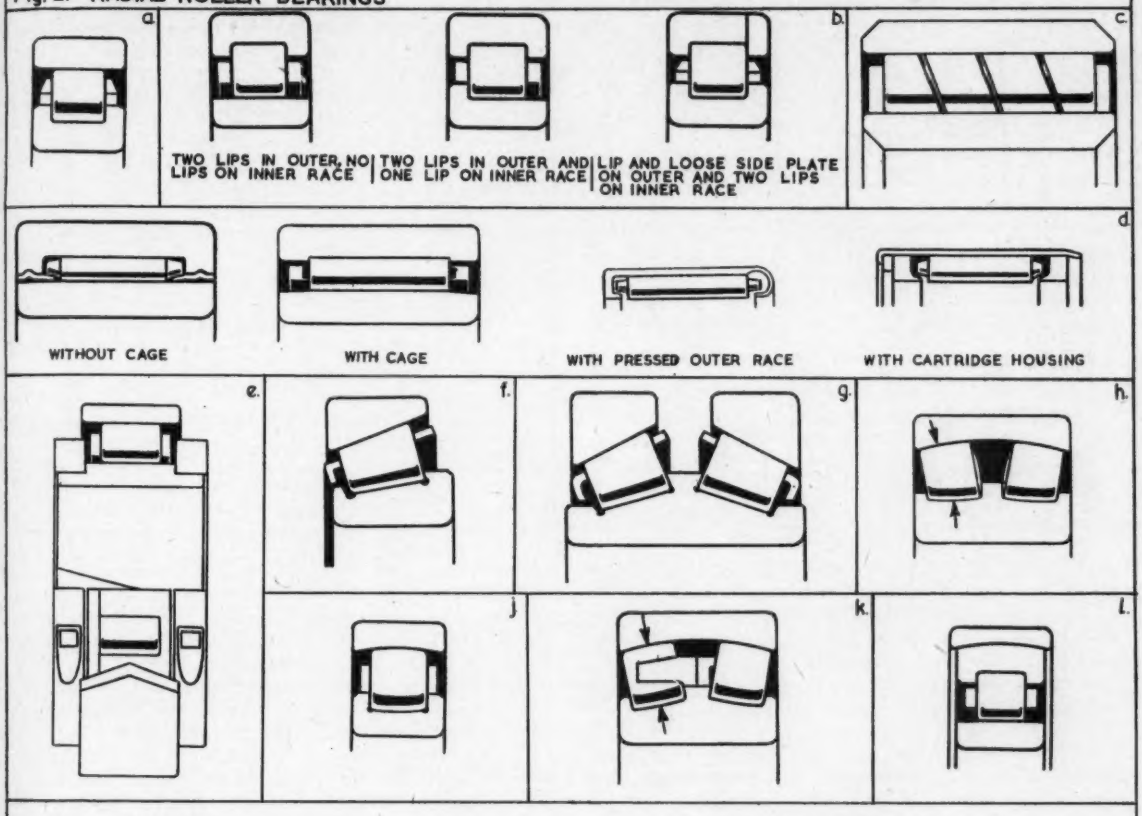
SELF-ALIGNING SINGLE-ROW BALL JOURNAL BEARINGS—These (Fig. 1 (j)) are basically rigid single-row ball journal bearings having a spherical outside diameter which fits in a seating with a spherical bore. It is by no means as satisfactory as the double-row type, and should only be used to correct initial misalignment, since it will not align under load. As the seating is soft, this type of bearing should not be used when heavy thrust loads are present.

Radial Roller Bearings

RIGID PARALLEL-ROLLER JOURNAL BEARINGS—The roller bearing has a higher radial load-carrying capacity than the ball bearing and it is also more capable of withstanding shock loads or vibration. The types with lips on both races are not normally recommended for use where continuous and heavy thrust loads are present; the limitation is not because of lip strength, but the ability of the sliding contact surfaces between the roller ends and flanges on the races to carry the load. Obviously, in these areas of sliding it is difficult to maintain the essential lubricating film, and this fact alone is probably the major limitation.

There are several types of the single-row bearing and four are shown in Fig. 2 (a) and (b). To prevent skewing, the rollers are guided by the flanges or lips on the inner or on the outer races. The most common types are manufactured with either the inner or outer races having no flanges or lips (Fig. 2 (a) and the first example in Fig. 2 (b)). These types allow limited free axial displacement of one bearing race relative to another, and this is useful

Fig. 2. RADIAL ROLLER BEARINGS



(a) Rigid parallel-roller journal bearing with integral lips on inner race.
(b) Rigid parallel-roller journal bearings, showing lip variations.
(c) Spiral roller bearing.
(d) Rigid needle roller journal bearing.
(e) Split rigid parallel-roller journal bearing.
(f) Single-row tapered-roller bearing.
(g) Two-row tapered-roller bearing.
(h) Spherical-roller bearing.
(j) Single-row barrel-roller bearings.
(k) Double-row barrel-roller bearing.
(l) Self-aligning parallel-roller journal bearing.

where expansion due to temperature is likely to occur. If shaft location is required in only one direction, the second type shown in Fig. 2 (b) is recommended, and if two-directional location is necessary, the third type shown in Fig. 2 (b) may be used.

In the types where one race is without lips this track may be convex ground to allow for slight misalignment or shaft deflection without edge loading of the rollers. An alternative method of obtaining this is to slightly convex the roller diameter. In these designs the rollers are normally retained by the cage in the flanged race and it is essential for the races not to be mixed, since parts are not interchangeable. Many manufacturers mark both races with a serial number and the user should always check that these are the same in the complete bearing.

Parallel-roller bearings are capable of high-speed operation, and for very heavy radial loads full-type bearings can be used. However, as explained previously, for full-type ball bearings, this design appreciably limits the maximum operating speed, and does increase the very low friction coefficient.

Similar types of bearings are also made with long rollers and more than one row of rollers. These design variations limit the maximum operating speed, but they increase capacity.

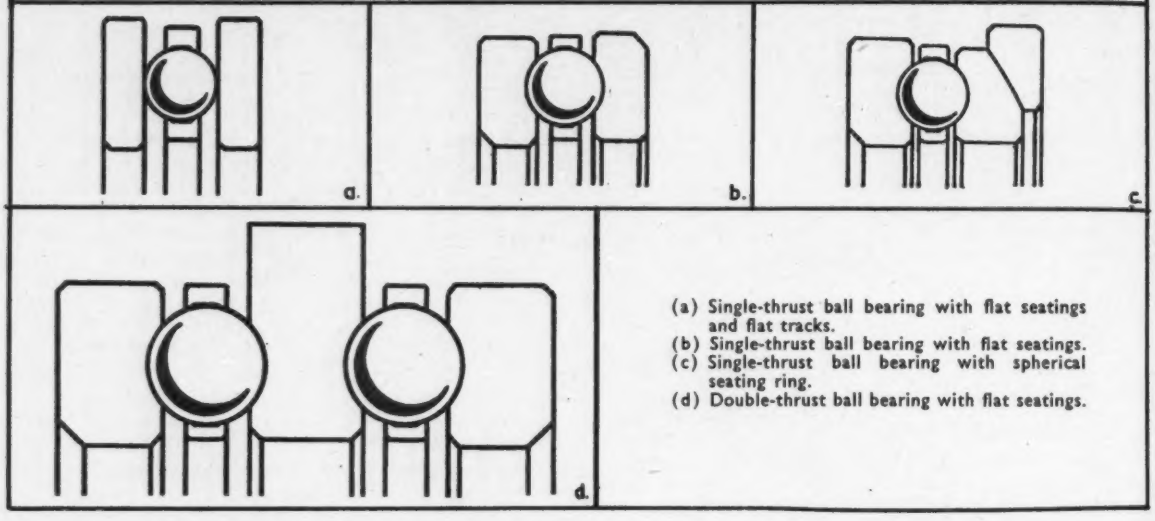
FLEXIBLE PARALLEL-ROLLER JOURNAL BEARINGS—Fig. 2 (c) shows a typical design of this type in which the rollers are manufactured from material wound in a helical form and then hardened and ground. They are invariably of the caged type, the rollers being retained in the cage by pillars through the centres of the rollers. To prevent the tendency of the rollers to skew, alternate rollers have left- and right-hand helices.

The construction results in a slight flexibility in the bearing with some advantage where shock loading is present, but the load-carrying capacity is lower than that of a similar bearing using the standard type of roller.

RIGID NEEDLE-ROLLER JOURNAL BEARINGS—These are a variation of the cylindrical roller bearing where the length of the roller is very much greater than the diameter. There are many variations within this range and some are shown in Fig. 2 (d).

Broadly, they are characterised by the fact that the bearing outside diameter to bore ratio is very much smaller than with the rigid parallel-roller journal bearing. They are manufactured as cageless types for high loads and slow speeds, with cages for the higher speeds, with and without inner races, with pressed and hardened outer races, and in cartridge housings. In the latter type the needle rollers are axially located by retaining plates, which are held in position by a cylindrical metal cartridge. The roller assembly is pressed out of the housing on assembly, the rollers running on the hardened surfaces on the shaft and in the housing. In such cases the contacting surfaces

Fig. 3. THRUST BALL BEARINGS



(a) Single-thrust ball bearing with flat seatings and flat tracks.
(b) Single-thrust ball bearing with flat seatings.
(c) Single-thrust ball bearing with spherical seating ring.
(d) Double-thrust ball bearing with flat seatings.

should be hardened to 60 Rockwell C. If the hardness is less than this, then a reduction in bearing capacity results. Also the depth of hard case is important and this depends upon the load to be carried. If the user is in doubt, he should consult the bearing manufacturer.

The types illustrated are not capable of carrying any thrust loads and other means are required to do this.

Needle-roller bearings are usually selected when lack of space precludes the use of any other type of bearing, and also this can frequently result in a more compact and economical design.

SPLIT RIGID PARALLEL-ROLLER JOURNAL BEARINGS—This is another most useful variation of the ordinary parallel-roller journal bearing and is illustrated in Fig. 2 (e). Each component of the bearing is split into two halves, the inner being split diagonally and the outer in a V form: this formation gives continuity of contact area and hence smooth running. The cage is also split, with the two halves butting up to each other.

The inner race has a cylindrical outside diameter and two split clamping rings fit over this and are screwed together by high tensile screws; these secure the inner race to the shaft and form the guiding flanges for the rollers. The split outer race is cylindrical and is retained in the housing; consequently, the fit of this race in the housing is most important.

The advantage of this bearing is in assembly, where a bearing of the one-piece construction might have to be passed over a long length of shaft to its seating, and, in replacement cases, where only a small amount of stripping may be necessary to replace a bearing of the split type.

TAPERED-ROLLER BEARINGS—The single-row bearing is shown in Fig. 2 (f). The conical construction is such that if lines are drawn coincident with the tracks and the roller surfaces, they meet at a common point on the bearing axis. This design ensures true rolling at the points of contact and results in a bearing capable of carrying radial or unidirectional thrust loads, or any combination of both. Frequently, the track of the cup is convexed slightly so as to give better load distribution along the roller length.

Since there is always a load component in the axial direction, the guiding flange on the cone will then be under load. As there is sliding between this and the roller ends, the manufacturers take great care in the design and manufacture of these surfaces. Some manufacturers grind a spherical surface on the guiding flange and also on the roller ends, as this assists in the maintenance of a lubricating film. It is essential to mount an opposed bearing to carry the induced axial resultant load, as relative displacement of the races will occur.

The contact angle varies according to service duty and manufacturer. The thrust capacity of the bearing largely depends on this angle and will increase with it.

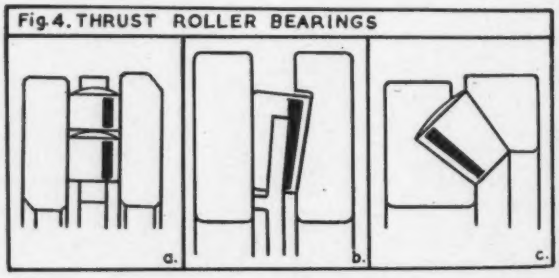
The cage retains the rollers and forms an integral unit with the inner race or cone. The coefficient of friction is slightly higher than for ball or cylindrical roller bearings.

The adjustment of the bearing, giving preload if required, is carried out by clamping the inner race: this ease of adjustment has an advantage in that shaft and housing fits are not so important as in ball or parallel-roller bearings, but care must be taken not to overadjust the bearing or a heavy preload will be imposed on it.

Tapered-roller bearings are also available as multi-row types, and Fig. 2 (g) shows a two-row tapered-roller bearing. This bearing has a double cup or outer race and single cones or inner races. They can be supplied with or without cone spacers. This spacer is of the required width to give the correct internal running clearance. If no spacer is required, the bearing is adjusted by clamping the inner races to give the required clearance. Tapered-roller bearings are capable of carrying high radial and thrust loads in both directions.

SPHERICAL-ROLLER BEARINGS—In this design the rollers are barrel shaped with one end having a smaller diameter, as shown in Fig. 2 (h). The track in the outer race is

Fig. 4. THRUST ROLLER BEARINGS



(a) Thrust parallel-roller bearing.
(b) Thrust tapered-roller bearing.
(c) Thrust spherical-roller bearing.

spherical so that the bearing is self-aligning. The central guiding flange has a spherical surface which is in contact with the spherical end of the rollers, the contact pressures depending upon the magnitude and direction of the load.

These bearings have a high radial load-carrying capacity and a good thrust capacity. In the narrow series the flange is retained in the outer race by elastic deformation, and this results in a lower load-carrying capacity.

BARREL ROLLER BEARINGS—In this design the rollers are barrel shaped, but, unlike the rollers in the spherical-roller bearing, they are symmetrical; the single-row bearing (Fig. 2 (j)) has a spherical outer track, so the alignment and the radial load-carrying capacity are good. The thrust capacity is low, due to there being a very small angle of contact.

In the double-row type (Fig. 2 (k)) the thrust capacity is improved due to the angularity of the rollers. The control over the rollers is not so good as in the spherical-roller bearing, since there is no axial component force to keep them in contact with the guiding flanges.

SELF-ALIGNING PARALLEL-ROLLER JOURNAL BEARINGS—These are rigid-type bearings having a spherical outside diameter and mounted in a spherical seating with a spherical bore (Fig. 2 (l)). Broadly, they have the same characteristics as the rigid types, with the advantage that they will correct initial misalignment.

Thrust Ball Bearings

SINGLE-THRUST BALL BEARINGS—These bearings are only capable of carrying thrust load in one direction. All types have a limited speed range due to the centrifugal force effect on the balls, which tends to fling them outwards, i.e., a resultant radial load which has to be carried by the bearing.

They are available with flat washers (Fig. 3 (a)) and grooved washers (Fig. 3 (b)). Due to the small area of contact between the balls and washers, the former type has a much reduced load-carrying capacity. The latter type is also available with a spherical seating ring (Fig. 3 (c)). This self-aligning seating will compensate for incorrect machining, but due to the high coefficient of friction between the seating and the washer it will not allow for shaft wobble, etc.

Thrust ball bearings are also made with an angle of contact between the groove and the balls. These types will carry radial as well as thrust loads.

DOUBLE-THRUST BALL BEARINGS—The design of these bearings is illustrated in Fig. 3 (d) and they are capable of carrying thrust load in either direction. The bearing is mounted on the shaft so that the centre washer can transmit the thrust load in either direction.

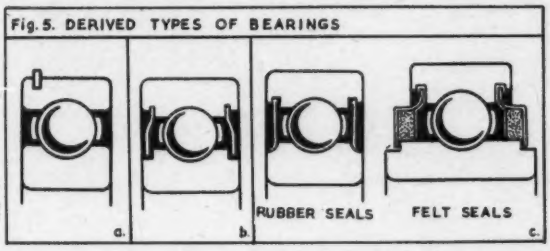
They are not capable of high-speed operation or of carrying radial loads. Double-thrust bearings are also obtainable with spherical seatings, but these will only correct initial misalignment.

Thrust Roller Bearings

THRUST PARALLEL-ROLLER BEARINGS—The normal construction of these (Fig. 4 (a)) is for one or more rows of rollers to roll between two flat washers, the rollers being retained in a cage. Due to the centrifugal force effect and the fact that the roller cannot roll over its whole length, there is a considerable speed limitation on their use. This departure from rolling is dependent upon the variation in radius of rotation over the roller length. To minimise this it is usual to use a number of shorter length rollers in each cage pocket. In order to utilise the whole tracking surfaces of the washers and to avoid any tendency of grooving, it is common practice to have rollers of different lengths and to vary their position from one cage pocket to another.

To improve the maintenance of a lubricating film and reduce the area of sliding between the roller ends, some manufacturers spherically grind one roller end and leave the other flat.

These bearings are capable of carrying very high thrust loads in one direction only and they can be manufactured with spherical seatings to cater for initial alignment errors. Since the washers are flat, they are capable of radial move-



(a) Rigid single-row snap ring type ball journal bearing.
(b) Rigid single-row ball journal bearing with two metal shields.
(c) Rigid single-row ball journal bearing with felt or rubber seals.

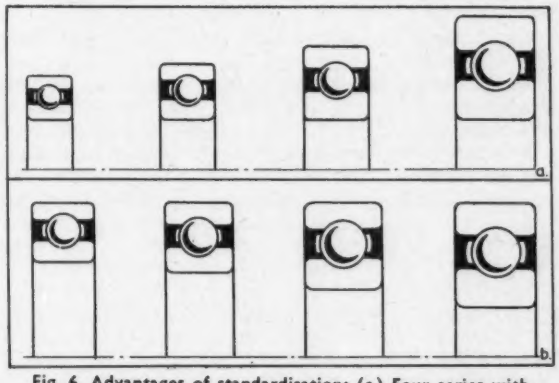


Fig. 6. Advantages of standardisation: (a) Four series with the same bore. (b) Four series with the same outside diameter.

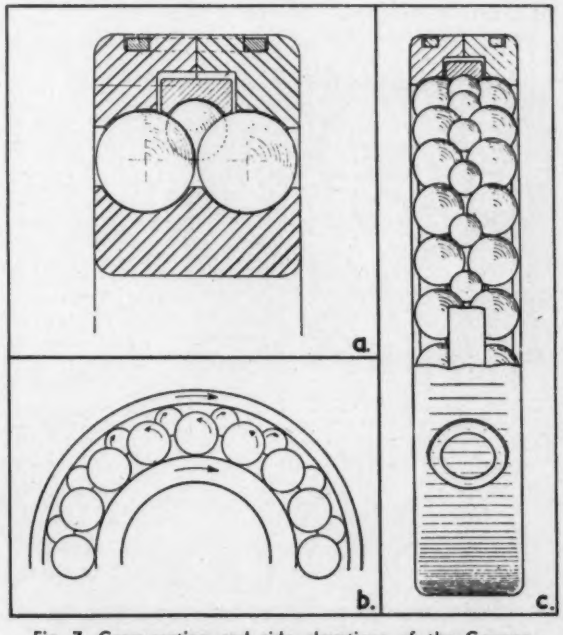


Fig. 7. Cross-section and side elevations of the German U.K.F. three-row ball race. (High Precision Equipment Ltd)

ment without additional loading of the bearing. Also, these bearings are available as the double-thrust type, i.e., to cater for heavy thrust in either direction, the construction being similar to the double-thrust ball bearing.

Both single- and double-thrust units can be obtained with spherical seatings.

THRUST TAPERED-ROLLER BEARINGS—The most popular type (Fig. 4 (b)) is designed with a flat washer located in the housing, and a washer with conical-shaped track located by the shaft. The radial component force caused by the angularity of the rollers is carried by the guiding flange on the shaft washer.

This design is capable of carrying very high thrust loads, but, due to the centrifugal force effect, it has a significant speed limitation. In the same way as the thrust parallel-roller bearing, it will cater for radial movement without imposing additional stresses on the bearing.

THRUST SPHERICAL-ROLLER BEARINGS—This design (Fig. 4 (c)) has an angle of contact between the rollers and tracking surfaces that is inclined to the shaft axis, and it is this feature that accounts for the type being able to withstand radial loads in addition to heavy thrust loads.

The outer track is spherical in form and the rollers are spherical, that is, barrel shaped with different diameters at each end. Consequently, these bearings have self-aligning features about the centre of the track of the outer race which is on the shaft axis.

Centrifugal force imposes a speed limitation, and the lubrication of this type of bearing is also most important if satisfactory service is to be obtained. From Fig. 4(c) it will be seen that, with the relatively large contact angle, an applied thrust load will induce a force against the roller guiding flange or lip on the inner race. This will depend upon the magnitude of the externally applied load, but the angularity will make it a high percentage of the applied thrust load. In addition to the resolved component of the thrust load plus a proportion of the radial load (if present), the centrifugal load has to be carried by this flange. Since there will be sliding between the roller ends and the locating lip, the bearing is normally designed with this guiding surface and the roller ends spherical in shape. These features assist in the maintenance of an efficient lubricating film.

Derivatives of Basic Types

When the basic types of bearing are modified externally, the general characteristics of the type are not appreciably changed. It is impossible to cover fully all the derived types, but mention must be made of a few of the more popular and useful ones:

BEARINGS WITH SNAP RINGS—These bearings are made to the same overall dimensions as the basic types with the addition of the snap ring groove and snap ring (Fig. 5 (a)). It forms a suitable and frequently very convenient method of providing axial location. It is widely used in the automotive industry where space is limited and costs all-important. In general, availability is confined to the rigid single-row ball journal bearings.

BEARINGS WITH INTEGRAL SHIELDS—These bearings may have the shield either on one or both sides and basically it is a development of the chip shield. There are many variations of the design and one of the more simple and widely used types is shown in Fig. 5 (b). In general, the shields take the form of a simple metal pressing retained in the outer race, and normally they can be fitted without increasing the overall dimensions of the bearing.

They are not intended to give maximum protection to the bearing, but they do assist in excluding foreign matter from entering the bearing and also in retaining the grease.

A bearing fitted with shields on both sides is not suitable for operation with oil lubrication. Oil can be used when one shield is fitted, it then performing as a chip shield. The fitting of shields does not decrease the load-carrying capacity of the bearing. They limit the maximum speed of a grease-lubricated bearing, due to the small space available for grease movement.

Broadly speaking, it is the rigid single-row ball journal bearings that are available with shields.

BEARINGS WITH INTEGRAL SEALS—These can be divided into two categories; first, where there is a clearance between the sealing members and the seal is of the labyrinth type, and, second, the rubbing-type seal. The choice between the two types depends upon the operating conditions, the most important factors being speed, operating temperature and type of foreign matter to be excluded. The contact-type seal is the most generally used integral seal in bearings, and the two most popular sealing mediums are felt and synthetic rubber; Fig. 5 (c) illustrates two typical designs using these media.

The object of the seal is to give efficient protection to the inside of the bearing and to prevent loss of grease from the bearing, and naturally they are attractive to the designer, since they frequently result in a more compact and simple design. However, he should bear in mind that sealed bearings are considerably more expensive than the basic type without seals. Also, the maximum operating speed is limited and frequently the life of the bearing is determined by the life of the initial grease packing of the bearing and not the fatigue strength of the bearing steels.

In addition, it is as well to note that the availability of sealed bearings is confined to a very limited number of basic types. Without doubt the most popular is the rigid single-row ball journal bearing, but the range is gradually being extended to include some types of parallel-roller, needle-roller and tapered-roller bearings. The designer considering the use of these bearings is recommended to contact the manufacturers in the early stages of his design to check the suitability and availability of the type and size under consideration.

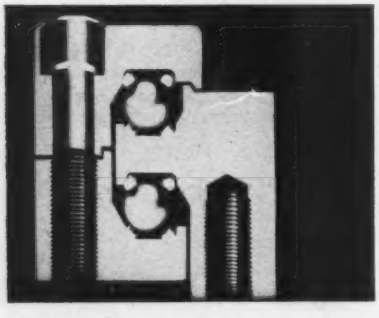


Fig. 8. Cross-section of a Roballo three-part anti-friction wire race bearing ring with internal spur gear.

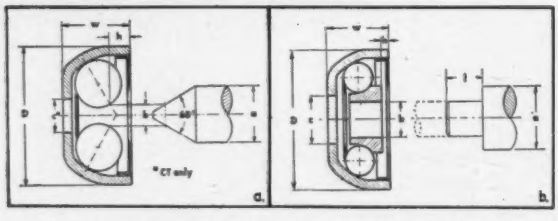


Fig. 9. Ransome & Marles' pivot bearings (a) without inner race and (b) with inner race.

Series Within the Basic Type

A bearing is a complete machine part in itself and lends itself to standardisation. It is only by rigid standardisation that batch or mass-production methods, and hence economy, can be achieved. This standardisation applies to the exterior dimensions only and it is the responsibility of the bearing manufacturer to fix the

interior dimensions of the bearing to give the best possible design.

The International Standards Organisation (I.S.O.) and the British Standards Institution (B.S.I.) have agreed on standards for a number of series within various basic types. However, much still remains to be done in this field.

Fig. 6 shows the make-up for the various series of the rigid single-row ball journal bearing; it can be seen that for one bore size there are four sections of bearing and likewise for one size of outside diameter. This variety of sizes gives the user a considerable number of standardised bearings from which to make his selection.

In addition to the standardisation of the external dimensions, i.e., bore, outside diameter and width, the tolerance on these dimensions and the corner radii have been standardised.

B.S. 292:1958 covers ball and parallel roller bearings (it does not include needle, tapered, barrel or spherical roller bearings) that have been standardised within the U.K. It should be noted that this standard includes the recommendation that "in the interest of simplification of standards it is recommended that users, in preparing new designs, should adopt metric size journal and angular contact ball bearings and parallel-roller journal bearings, in preference to inch-size bearings of these types".

High-precision Bearings

As is well known throughout the engineering industry, anti-friction bearings are made to a high degree of accuracy, and for the vast majority of applications the standard product will entirely satisfy. However, in a number of applications such as machine tool spindles, gyros, ultra-quiet electric motors, etc., it is necessary to use bearings manufactured to even closer internal tolerances. For this reason the larger ball bearing manufacturers produce bearings which are basically the same as standard, but are more accurate. In many cases there are a number of these quality grades. It is only by experience and working in close co-operation with the manufacturers that it is possible to specify the correct quality grade required. The user should note that there is a big price differential between these bearings and the standard ones, so indiscriminate specification of these higher quality grades can result in considerable unnecessary expense.

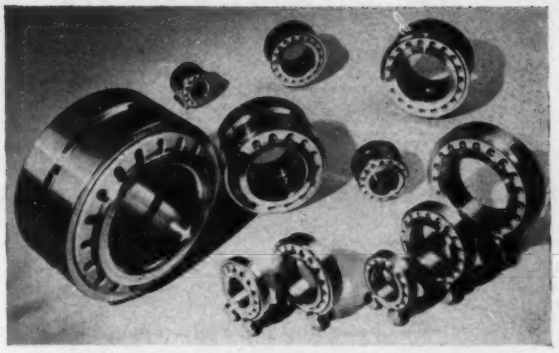


Fig. 10. Selection of Gamet single- and double-row roller bearings.

With the diversity of bearing types and applications it is impossible to state in a few words any guiding rules that would not have many exceptions. When referring to manufacturers or their catalogues, it is essential to consider the basis on which the stated load ratings or capacities have been arrived at; that is to say, the theoretical expected lives and speeds at which the quoted figures are valid.

PRINCIPAL MANUFACTURERS OF BALL AND ROLLER BEARINGS

U.K.

Autoset (Production) Ltd.
Ball and roller bearings for conveyors, mowing machines, etc.

B.M.B. Co. Ltd.
Miniature precision ball and thrust bearings.

Blackwell Bearings Ltd.
Solid roller cages with solid or split races.

British Timken Ltd.
Taper roller bearings.

Cooper Roller Bearings Co. Ltd.
Ball thrust bearings; split roller bearings; solid roller bearings; needle roller bearings; flat thrust roller bearings.

W. E. Cramp & Sons (Tipton) Ltd.
Non-precision and pressed ball bearings; pressed thrust bearings; cylindrical roller bearings.

E.M.O. Instrumentation Ltd.
Precision ball bearings for instruments, servo-motors, etc.

Fischer Bearings Co. Ltd.
Ball journals; thrust races; roller bearings.

Gamet Products Ltd.
Taper roller bearings for machine tools.

Hoffmann Manufacturing Co. Ltd.
Roller bearings; needle bearings; ball bearings; thrust bearings.

Ina Needle Bearings Ltd.
Needle bearings.

Pollard Bearings Ltd.
Ball and roller bearings.

Ransome & Marles Bearing Co. Ltd.
Roller journals (rigid and self-aligning); needle roller bearings; ball journals (rigid and self-aligning); thrust bearings.

Geo. Salter & Co. Ltd.
Flexible roller bearings; solid roller bearings; needle roller bearings.

Skefco Ball Bearing Co. Ltd.
Ball bearings; thrust bearings; roller bearings; taper roller bearings; needle bearings.

Spiro Ball Bearing Co. Ltd.
Precision ball bearings.

Torrington Co. Ltd.
Needle bearings; thrust bearings.

U.K. AGENTS OF FOREIGN MANUFACTURERS

U.S.A.

Barden Corp., Quality Bearings Ltd.
Fafnir Bearing Co., E. J. Jack Ltd.
Federal-Mogul-Bower Bearings Inc., Industria (Bearings) Ltd.
Hyatt Bearings Div. General Motors Corp., A.C.-Delco.
SKF Industries Inc. (SKF/Hess-Bright, Tyson), Industria (Bearings) Ltd.
Industrial Tectonics Inc. (I.T.I.), Insley Industrial Supply Co. Ltd.
Kaydon Enginering Corp., Industria (Bearings) Ltd.
Link-Belt Co., E. J. Jack Ltd.
Marlin-Rockwell Corp. (M.R.C.), Industria (Bearings) Ltd.
McGill Manufacturing Co. (McGill, Camroll, Guideroll), E. J. Jack Ltd.
Miniature Precision Bearings Inc. (M.P.B.), E. J. Jack Ltd.
Norma Hoffmann Bearings Corp, Universal Ball Bearing Repair & Mfg. Co.
New Departure Div. General Motors Corp. (N.D.), A.C.-Delco.
Orange Roller Bearing Co. Inc., E. J. Jack Ltd.
Roller Bearing Co. of America (R.B.C., Pitchline, 20th Century), E. J. Jack Ltd.
Rollway Bearing Co. Inc. (Rollway), E. J. Jack Ltd.
Timken Roller Bearing Co. (Timken), British Timken Ltd.
Tyson Bearing Co. (Div. of SKF), Industria (Bearings) Ltd.
Torrington Co. (Torrington), Torrington Co. Ltd.

EUROPE

Dürkoppe Werke Aktiengesellschaft (D.W.B.), Flexicon Ltd.
Kugelfischer Georg Schäfer & Co. (F.A.G.), F.A.G. Bearing Co.
Georg Muller Kugellagerfabrik (G.M.N., Kugelmuller), Industria (Bearings) Ltd.
Universal Kugellager Fabrik G.m b.H. (U.K.F.), High Precision Equipment Ltd.

Nadella, S.A., des Roulements a Aiguilles, Insley Industrial Supply Co. Ltd.
Les Application du Roulement (A.D.R.), Ransome & Marles Bearing Co. Ltd.

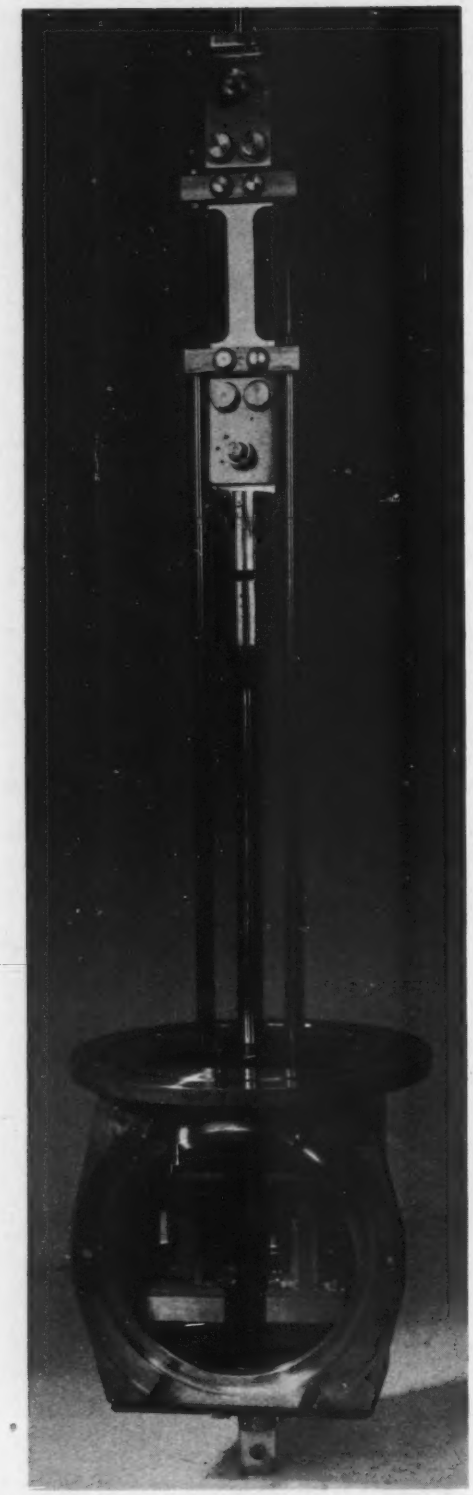
R.M.B. Roulements Miniatures, S.A. (R.M.B.), Miniature Bearings Ltd.

R.I.V. Officine di Villar Perosa (R.I.V.), Universal Ball Bearing Repair & Mfg. Co.

Steyr-Daimler-Puch (Steyr), Universal Ball Bearing Repair & Mfg. Co.

The above list includes principal makers who have kindly collaborated in the preparation of this survey.

WIDER APPLICATIONS FOR NUCLEAR MATERIALS



Creep tests on reactive materials such as thorium and zirconium have to be made in an oxygen-free atmosphere. Specially-purified argon is used in this creep machine developed by the British Non-Ferrous Metals Research Association.

Uranium and thorium, together with a number of other radioactive materials, have some promising applications in industry outside the immediate nuclear field. Here is described their development and the growing market for radioisotopes

by T. H. H. SKEET, LL.B.

ALTHOUGH uranium has been produced in the Belgian Congo and Canada for many years, it was not until the advent of the atomic bomb that its potentialities for power generation began to be appreciated. Apart from the nuclear application, there is also a small market for uranium and its salts in several branches of industry, e.g., commercial gas discharge devices.

It is also noteworthy that, although the traditional outlet for thorium was in the manufacture of incandescent gas lamps (which the introduction of electricity greatly diminished), post-war research uncovered a number of promising uses, among which nuclear development is perhaps the most intriguing. Contemporary uses are indicated in Table 1, but of special interest is a process developed for the production of thorium of reactor-grade purity through the treatment of thorium-nitrate. After processing, a product containing 99·89 per cent of thorium has been recovered.

An assessment of the potentiality of uranium, thorium and associated materials in the nuclear field requires a brief outline of the planned future development of the U.K. industry.

The necessity for building reactor systems capable of economic operation at a falling load factor (eventually between 50 and 60 per cent, which must inevitably occur as nuclear installations supply an increasing proportion of the U.K.'s total power requirements) and relatively competitive with conventional fuels has led to considerable modification of the original gas-cooled graphite-moderated reactor at Calder Hall. Improvements have been incorporated in the stations now under construction, but a further reduction in capital costs calls for a substantial increase in the gas outlet temperature, which currently approximates 400 deg. C. This should be raised to 500-575 deg. C. in the A.G.R., leading to greater thermal efficiency in nuclear stations built during the mid-'sixties. Another objective is to increase fuel element ratings by improving the heat transfer to the coolant gas.

Both these points may be achieved by using ceramic fuel in the form of sintered uranium oxide, instead of metallic units at present employed, and by cladding the fuel elements in a new canning material (such as beryllium) which has a better performance at high temperatures than the conventional magnesium cans. Unit costs for nuclear power stations embodying these features and operating at a 60 per cent load factor are likely to reveal an improvement approaching 20 per cent over contemporary plants.

There are several materials eligible for canning, three of which are of particular interest: beryllium, zirconium and stainless steel. While the latter is the least expensive, it suffers the disadvantage of a relatively higher neutron cross-section, which may seriously affect the reactor performance. Neither beryllium nor zirconium suffers this

handicap, but they are either expensive to fabricate or move in a somewhat restricted market. The likely candidate is beryllium, due to its neutron economy, compatibility with uranium and corrosion resistance to CO_2. Experimental beryllium cans have been subjected to intense radiation without displaying significant damage. Though zirconium is promising in water-cooled reactors it is unsuitable in gas-cooled systems, since it reacts with the coolant at temperatures over 500 deg. C.

It is thought that while metallic fuels have an effective burn-up of some 3,000 MWD/ton in the initial power stations, their life may possibly be doubled by technical advances. Above that figure to about 10,000 MWD/ton, ceramic fuels are likely to play a leading role. Though enrichment of the uranium and the use of beryllium canning will add to fuel element costs, this will be more than offset by greater efficiency, leading to the extraction of about twice the amount of heat per ton of fuel employed. A burn-up time of 25,000 MWD/ton is foreseen for UO_2.

Further, while the melting point of UO_2 is approximately 2,400 deg. C., permitting improved fuel element ratings, its thermal conductivity is low (due partly to the continuous formation of cracks), necessitating the use of a great number of pencil-like rods of uranium oxide. It is thought, however, that low conductivity tends to diminish with increased temperature and exposure to radiation.

The difficulty with the metallic fuels is their dimensional instability, particularly due to the appearance of wrinkling at low temperatures and to swelling, which is probably intensified with greater heat. This is eliminated with ceramic materials, which are also particularly favoured for their compatibility with the coolant gas, CO_2, and beryllium canning materials. Though cracking may occur, this need not prove injurious if the element is adequately accommodated in the metal can.

The application of plutonium for use in commercial reactors is being closely studied, but much research will be required to fully appreciate its technology. By recycling PuO_2 in appropriate reactor systems, U.235 enrichment for the replacement charge may be reduced. Due, however, to its low melting point in metallic forms (640 deg. C.), a suitable alloy must be prepared for reactor use. In this connection, beryllium, zirconium and thorium have all been considered as possible alloying materials. In the commercial stations which follow the A.G.R. prototype, plutonium will probably be recycled in the form of PuO_2 or Pu_2O_3. This is expected to have the advantage that a reactor requiring an initial charge of enriched uranium may be continued operating on a feedstock of U.238 and ultimately attain a higher burn-up of the natural uranium.

The performance of fuel elements will be carefully studied in the new low-power research reactor H.E.R.O., which is being built at Windscale adjacent to the A.G.R. prototype. The latter is expected to be completed in 1961 and a commercial unit in operation in the latter half of the 'sixties.

Development beyond 1970 is likely to centre on two systems—the H.T.G.C.R. and the fast breeder reactor. The potential of the former (which may be important for ground and marine propulsion) will be studied in a high-temperature zero-energy system now under assembly at Winfrith Heath. In this instance, it is expected that a ceramic fuel element comprising a mixture of uranium (highly enriched) and thorium carbide is likely to be used in an impervious graphite sheath. Fuel element temperature is likely to reach 1,300 deg. C. and gas outlet temperature above 700 deg. C. The difficulty in entrapping gaseous fusion products has apparently been overcome by the production of graphite on an experimental scale capable of satisfactory performance at high temperatures. The Hawker Siddeley-John Brown Nuclear Construction Co. are reported to have developed a graphite fuel container capable of satisfactory performance at about 800 deg. C.

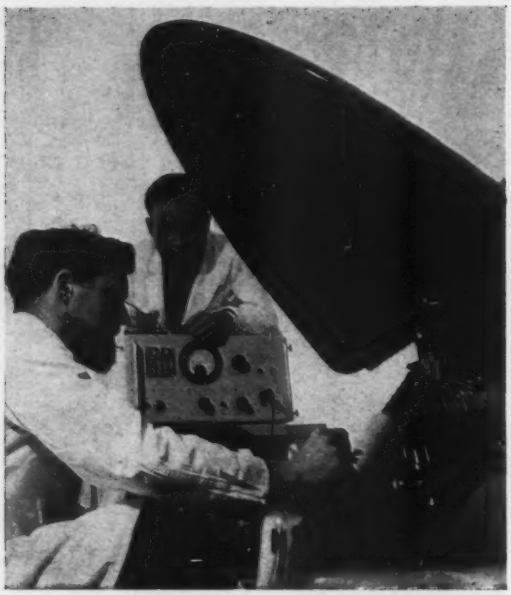
TABLE I. Industrial uses of thorium

Application	Properties Used
Incandescent mantles for gas lights and pressure lamps.	Combustible woven cotton or rami impregnated with 99 per cent thorium oxide and 1 per cent cerium oxide provides luminosity.
Commercial X-ray tubes.	As a target.
Photoelectric cells and glow discharge tubes.	Photoelectric properties.
Ductile tungsten filament wire coated with 0·75 per cent thorium in filaments for high-voltage rectifiers, electronic and radio valves.	Thoriated tungsten filaments have high resistance to shock and increase the emission of electrons at low temperatures
Catalysts for petroleum cracking and in the chemical industry.	High melting point and sintering temperatures.
Magnesium-thorium alloys containing about 3 per cent thorium envisaged for aircraft development work.	Imparts good ductility to the alloy and exceptional stability following heat treatment. Retain light weight and corrosive resistance of other magnesium alloys. Also maintains performance at high temperatures. Metal sheets produced from the alloy can withstand temperatures of 300 deg. C. for long working periods. The alloy is fabricated and machined as other magnesium alloys.
Thorium in conjunction with:	
Cu and Ni (thorium content 5%)	
Fe " " (" " 10%)	High temperature performance, chemically resistant and mechanically strong.
Cr " " (" " 4%)	
Refractories.	High melting point and stability at high temperatures.
Nuclear.	Infra.
Closely-related Radioactive Elements	
Mesothorium and radiothorium for testing microscopic leakages of air and dust through protective masks.	
Reducing fire hazard in handling petrol, explosive vapours and inflammable substances due to static electricity.	Due to ionizing power, air is rendered a good conductor, enabling the accumulation of static electricity to be discharged through vantage points with safety.
Small quantities of mesothorium and thorium compounds are used in conjunction with zinc sulphide to render permanent luminosity of figures and hands on instruments and dials.	Radiation emitted by mesothorium continuously excites light emission and thorium acts as an activator.
Medicinally in the treatment of cancer and skin infections.	Radiation.
Radiothorium—in laboratory research.	Emission of alpha rays.

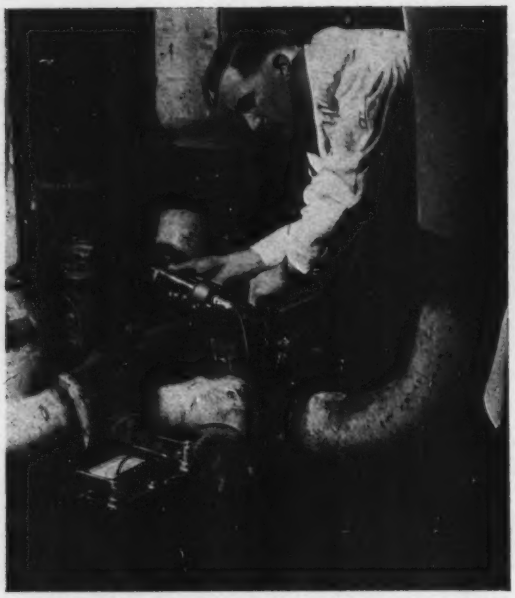
The technology of the fast breeder system is now being actively studied at Dounreay, but due to development problems it is not anticipated that a commercial plant will be built until after 1970. Primary fuel is either U.235 or plutonium in the core, around which is set a blanket of U.238 and thorium; it is perhaps significant that commercial development has been deferred for at least ten years, when substantial supplies of plutonium fuel from the civil power programme will be coming available.

As the unit produces more plutonium than it consumes, exceptionally low fuel charges are foreseen and a supply of fissionable material may be made available for other reactor systems. Though the initial inventory requires a substantial quality of highly enriched fuels (such as U.235, Pu.239 or U.233), once it is in operation depleted uranium, U.238, or thorium may be employed, thus rendering the U.K. less dependent on U.235, which is relatively scarce.

The system does not require a moderator, and the heat engendered in the core is transferred by liquid metal or other non-moderating coolants, such as a sodium-potassium alloy to primary (uranium core) and secondary (thorium blanket) heat exchangers which are clad in niobium and stainless steel respectively. The niobium enclosing the uranium rods has, apart from a high melting point, resistance to chemical attack by either uranium or radium. If it is proved that more heat can be extracted for each ton of uranium through the use of liquid sodium, and the fire risk obviated, the reactor could itself be smaller with a consequent reduction in capital costs. The question of sodium compatibility has yet to be determined. It is interesting to note that the feasibility of using radioactive sodium as a source of radiation for industrial pro-



Inspecting a car engine for fuel leaks using palladium 109 in the form of a petrol-soluble compound.



Another use for isotopes: using a thickness gauge for measuring pipework.

cessing is being examined in the U.S.A.

As previously indicated, there is little likelihood of thorium effecting any promise in the atomic energy field before 1970. Small quantities will, however, continue to be required, principally for incandescent mantles, X-ray and electronic equipment. In these applications the market, though small, is expected to grow.

There is now only one company in the U.K. producing thorium finished products, namely Thorium Ltd., an associate of I.C.I. Thos. Firth & John Brown Ltd. formerly produced metallic thorium as a fuel for nuclear reactors, but its functions have been assumed by the A.E.A. itself since the end of 1958.

Using Radioisotopes

In recent years a number of radioisotopes have become available for a host of industrial applications. These, in fact, comprise a number of materials which have been activated through exposure to a neutron source in a reactor system. Isotopes of growing importance in industry include cæsium 137, carbon 14, cerium 144, cobalt 60, gold 198, iridium 192, iodine 131, lead 210, phosphorus 32, polonium 210, radium 226, ruthenium 106, sodium 24, strontium 90, sulphur 35, thallium 204 and thulium 170. They possess the characteristic of emitting radiation, which may be detected by instruments and recorded. For example, millions of feet of oil-well bores are logged annually by neutron sources. Polonium-beryllium enclosed in a small container is utilised to give an analysis of borehole strata, signifying particularly the oil and water content.

The displacement of silt in rivers and harbours may be examined with the aid of radioactive tracers, and through the use of gold and tritium the flow of rivers may be gauged and data collected which have an important bearing on water resources for hydro projects and irrigation control.

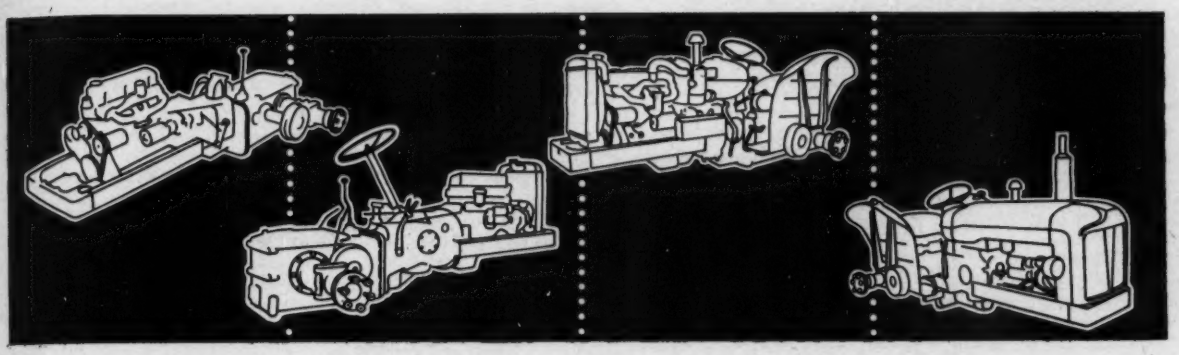
Due to the ease in detecting the presence of neutron sources, radioisotopes have found increasing use in detecting leaks in such cases as buried conduits and complicated runs of pipes, or the exact location of an obstruction in an extensive overland oil pipeline network. In the former case, after introducing a pulse of krypton 85 into the circuit, its transit time and concentration may be measured at selected points. In the latter instance, a cobalt source is introduced into the pipe and its position recorded at intervals by external recordings of the gamma rays emitted. The percolation of waters into the Severn Tunnel has been successfully measured by the employment of sodium 24.

Through the use of a polonium alpha-particle camera it is possible to measure minute differences or changes with accuracy. Thus, microscopic alterations in the density of paper passing between the camera's eye and a photographic strip can be detected rapidly and continuously. Not infrequently, the presence of a minute quantity of impurities may radically alter the performance of materials, but in minute quantities variations from sample to sample would be difficult to assess if it was not for radioactivation analysis.

These illustrations are an indication of the immense field opened up by this new tool of industry. In the realm of industrial chemistry their value has scarcely been exploited. Oil refining, petrochemical development and synthetic fibre manufacture are all likely to benefit greatly by this relatively recent innovation, and a host of other applications has been opened up in a wide range of industries and vocations, including medicine, pest control, foodstuffs and agriculture. Their value in industry may be gauged from the fact that they have saved the U.S.A. about $406 million a year. In the U.K. annual output of radioisotopes is valued at no less than £600,000 a year, a figure which is likely to double by 1963.

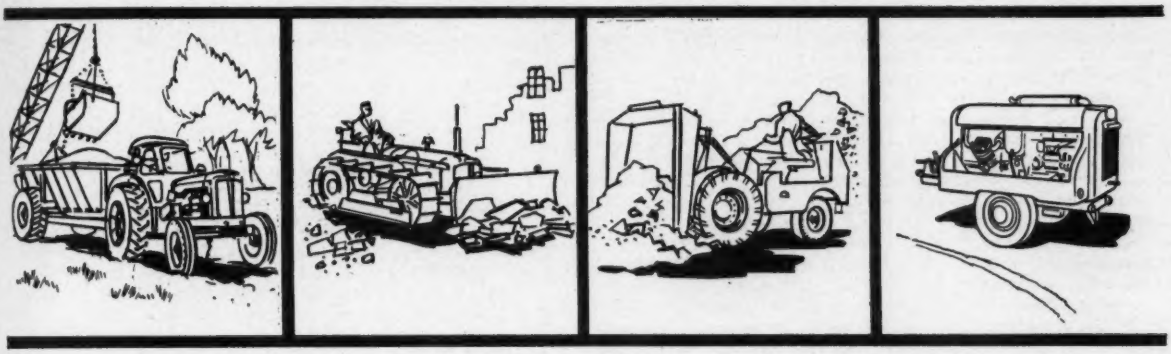
Research work by the U.K.A.E.A. on the commercial-scale use of intense radiation for industrial purposes has now reached the stage at which a pilot plant is being built for operation at the end of this year. It is expected to be the first of its kind and size in the world.

The plant, being built at Wantage, will enable industrial firms already investigating the technical merit and commercial potentialities of irradiated materials to carry out full-scale trial runs of irradiation processes, such as the sterilisation of medical equipment and the disinfestation of packaged products.

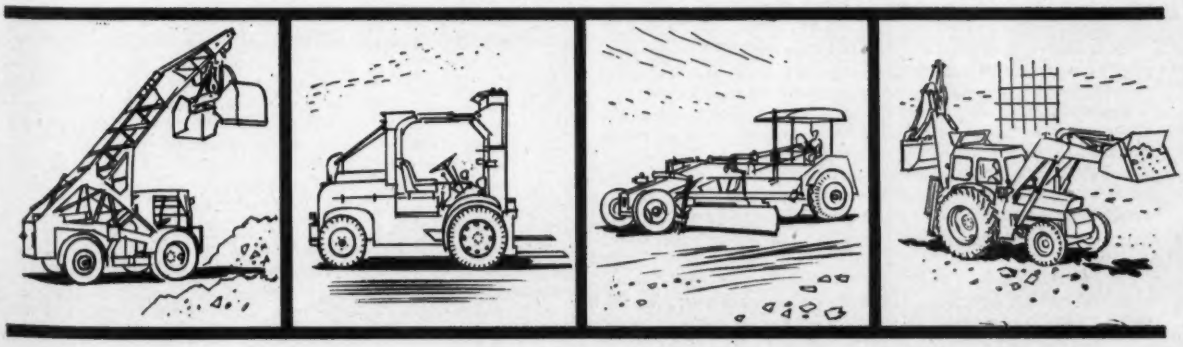


Designers looking for a 'sales plus' specify

Fordson Power



They look for Fordson Power because it gives equipment the stamp of reliability, ensures high output at low cost, and because it has the backing of the Ford world-wide service and spares organisation. There are Fordso. Industrial Units in the 30-40 and 40-50 b.h.p. classes, in more than 100 different assemblies. Fit Fordson and you get all the benefits of quality mass-production from Ford's famous Dagenham factory, the biggest producer of mobile power units. Fit Fordson, the unit tailor-made to your requirements. Send for detailed specifications today.



Wise buyers insist on **Fordson Power**

INDUSTRIAL SALES DEPARTMENT, TRACTOR DIVISION
FORD MOTOR COMPANY LIMITED, DAGENHAM, ESSEX

LINEAR ENERGY ABSORBERS

A linear energy absorber can be chosen from two groups: one group absorbs the energy of impact, retaining it until some manner of release is provided; the other dissipates the energy of impact, either completely or to a major extent. Factors to consider before selecting or designing either type are:

1. Mass and velocity of the object to be stopped.
2. Maximum stress permissible in object during stopping period.
3. Stopping distance.
4. Available space and allowable weight for the energy absorber.
5. Cost of the energy absorber.

ENERGY STORERS

This group absorbs the energy of impact for later release. Various types of springs, including liquid springs and air cylinders, perform in this manner. These latter types are particularly useful for dashpots where small momentary shocks are to be absorbed, or where energy of motion should be conserved for subsequent reversal of travel. Such types as rubber pads and heavy impact pendulums are not discussed, primarily because they are difficult to analyse accurately.

Helical Springs. This, the simplest and most common energy absorber, has a straight load-deflection curve. Energy to be absorbed by the spring is given in general form by Eq. 1 and is also represented by the area under the curve.

The force acting on the object, and therefore the stress on the object, increases linearly with the deflection. Consequently, the maximum stress is twice the average stress. Energy stored in the spring can be used to return the object to its initial position or can be dissipated for some other purpose.

Volute Springs. When the energy to be absorbed is high and the space somewhat limited, a volute spring can be used more advantageously than the helical spring. It has a non-linear load-deflection characteristic in which the deflection is proportional to the developed length of the coils and is considerably more complex in design. The initial part of the deflection is at a constant rate, and when the first element becomes inactive the process of reducing the number of active coils begins with a transition from the original spring rate to higher rates.

The area under the curve again equals the energy absorbed by the spring. For this case, the maximum load is more than twice the average load, and the maximum stress of the object being stopped will be greater than it would be for helical springs.

Leaf Springs. Multiple-leaf springs find limited use as energy absorbers, but are inherently self-damping because of friction between adjacent leaves.

Conical-Disc Springs. The Belleville or conical-disc spring can also absorb more energy in a given space than the helical spring and may be arranged in stacks. They are most applicable for a large load and small deflection. They possess inherent damping characteristics similar to leaf springs, and oscillations soon die out after impact.

Load-deflection curves depend upon spring design and may vary from an almost straight line to a very definite curve, which permits a good ratio of maximum stress to average stress.

Liquid Springs. Special oils or fluids are used to make liquid springs that can exert as much as ten times the force of helical springs for the same amount of space.

Air Cylinders. Rapid compression of air can be considered to be adiabatic. The pressure/volume relationship is shown by the exponential curve and by Eq. 4 and 5. By the use of Eq. 6 and 7, the curve of force-deflection is obtained as the reverse of the pressure-volume curve.

As before, the area under the force-deflection curve represents the energy absorbed by the air. Area under the pressure-volume curve also equals the energy absorbed, as given by Eq. 8. For the adiabatic process, Eq. 9 is obtained.

This method is approximate and must be checked by experiment, since piston friction has been ignored.

Another point of interest as noted from the pressure-volume curve is that maximum pressure, and therefore maximum stress, is considerably greater than the average pressure. A bleed orifice can easily be placed in the end of the cylinder to dissipate the energy, but the calculations are considerably more complex.

ENERGY DISSIPATORS

Energy absorbers might almost be termed "linear brakes", because they stop motion and dissipate energy.

Ring Springs. Although marginal, ring springs are placed in this group because they do dissipate absorbed energy as friction between their sections in a few cycles. This type of spring has a high load capacity for its size and weight and will absorb linear energy with little recoil. Having a linear load-deflection characteristic like the helical spring, the ring spring exerts a maximum stress in the object being stopped equal to twice the average stress.

Variable-pressure Shock Absorbers. A popular device for absorbing linear energy is the hydraulic shock absorber. The most common type has a constant-area metering orifice which causes pressure in the cylinder, and therefore a force acting to stop the object, to be proportional to the square of the velocity of the object as indicated by the force-deflection curve.

Energy absorbed is given by Eq. 10, and the energy given up by the object being stopped is given by Eq. 11. Setting these two relationships equal to one another results in Eq. 12. This expression implies theoretically that the final velocity can never be brought to zero because the value of the natural logarithm would then become infinite. However, for purposes of calculation, the velocity can be reduced to a very small value, which is the same as stopping the moving object. Maximum pressure occurs at the beginning of the stroke, where the initial and final velocities are equal, and can be determined through Eq. 13 and 14.

The constant-area orifice shock absorber can only slow the falling object to the point where the resisting force is equal to the weight or force exerted by the object. Depending upon the weight, a severe shock could result at the end of the stroke.

Constant-pressure Shock Absorbers. These devices, where cylinder pressure is constant and very nearly equal to the calculated average pressure, permit a considerably reduced stress in the object being stopped, with resultant weight and space savings in the stopping mechanism. Such a shock absorber has a varying fluid-discharge area which is carefully calculated to give constant cylinder pressure and, thus, constant resisting force.

To compare the variable-pressure shock absorber with the constant-pressure type, the average pressure can be found from $P_{ave}AS = (mv^2)/2$. For the values given in the example for variable-pressure absorbers, average pressure is found to be 6,210 p.s.i., compared with a maximum pressure of 37,100 p.s.i. In a constant-presure absorber, this lower pressure could stop the same load in the same distance.

In effect, with this constant-pressure shock absorber, about one-sixth of the pressure is used for equivalent "stopping power". Obviously, system stresses are less and sealing is much easier. This ideal case is represented in the force-deflection diagram.

The relationship of discharge area versus piston travel is found from Eq. 15, which combines Eq. 10 and 11. Eq. 16 is obtained from Eq. 14. Fluid velocity is found by a ratio, Eq. 17. Differentiating both sides of Eq. 15 with respect to time, dividing by dS, combining terms, and substituting the basic definition of "a" into the result gives Eq. 18. This equation determines the orifice area for any point in the stroke of the shock absorber.

For a vertically falling object, additional energy, equal to weight times distance, must be absorbed and dissipated. This modification is shown in Eq. 19. The acceleration is a constant and can be determined by Eq. 20.

"Single-shot" Shock Absorbers. Similar to the constant-area absorber is the plastics extrusion type in which a viscous plastics substance is extruded from a constant area orifice or nozzle.

With this system, rate of energy absorption is proportional to the rate of extrusion, and maximum resistance will be exerted at the beginning of the stroke where the velocity is greatest. The force will then decay exponentially, as shown for the constant-area orifice hydraulic shock absorber.

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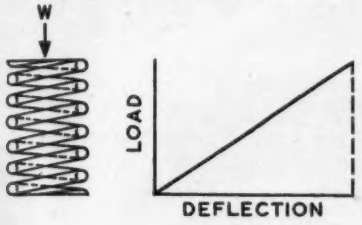
HELICAL SPRINGS



$$E = \frac{1}{2} mv^2 \quad (1)$$

$$E = \frac{1}{2} kS^2 \quad (2)$$

$$E = \frac{1}{2} mv^2 + WS \quad (3)$$

EXAMPLE 1: Find spring rate. S = 6; v = 30; W = 100. Using Eq. 1,

$$E = \frac{1}{2}\left(\frac{100}{g}\right)30^2 = 1{,}400 \text{ ft.-lb.}$$

and, solving Eq. 2 for k,

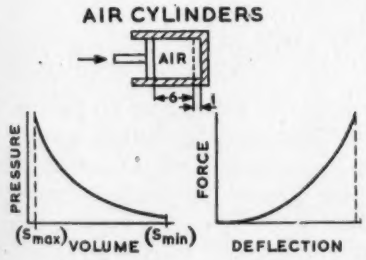
$$k = \frac{2E}{S^2} = 933 \text{ lb. per in.}$$

EXAMPLE 2: Find spring rate, weight falling vertically. S = 6; v = 30; W = 100. Solving Eq. 2 for k and combining with Eq. 3,

$$k = \frac{mv^2}{S^2} + \frac{2W}{S} = \frac{\left(\frac{100}{g}\right)30^2}{6^2} + \frac{2(100)}{6}$$

$$= 965 \text{ lb. per in.}$$

AIR CYLINDERS



$$pV^n = \text{Constant} \quad (4)$$

$$p_1V_1^n = p_2V_2^n \quad (5)$$

$$F = PA_p \quad (6)$$

$$SA_p = V_1 - V_2 \quad (7)$$

$$E = \int pdV \quad (8)$$

$$E = \frac{p_2V_2 - p_1V_1}{1 - n} \quad (9)$$

EXAMPLE: Find diameter of piston. E = 1,400; n = 1·4; p_1 = 14·7; S = 6; v = 30; W = 100; $V_2 = V_1/(6 + 1) = V_1/7$. Rearranging Eq. 5,

$$\frac{p_2}{p_1} = \frac{V_1^n}{V_2^n} = 7^{1.4} = 15.6$$

Substituting in Eq. 9 and rearranging,

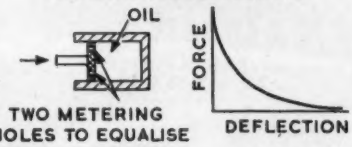
$$E = \frac{p_1\left(\frac{p_2}{p_1}\frac{V_1}{7} - V_1\right)}{1 - n}$$

$$V_1 = \frac{1{,}400(1 - 1.4)}{14.7\left(\frac{15.6}{7} - 1\right)} \times 12 = 372 \text{ cu. in.}$$

then,

$$d = \left(\frac{4V_1}{\pi S_1}\right)^{\frac{1}{3}} = \left[\frac{4(372)}{3.14(7)}\right]^{\frac{1}{3}} = 8.22 \text{ in.}$$

VARIABLE-PRESSURE SHOCK ABSORBERS



TWO METERING HOLES TO EQUALISE FORCE ON PISTON

$$E = \int_0^{S(max)} FdS \quad (10)$$

$$E = \frac{1}{2} m(v_1^2 - v_2^2) \quad (11)$$

$$\ln \frac{v_1}{v_2} = \frac{wA_p^3S}{3{,}456\, c^2A_o^2W} \quad (12)$$

$$F_{max} = P_{max}A_p \quad (13)$$

$$P_{max} = \frac{wA_p^2v_1^2}{288gc^2A_o^2} \quad (14)$$

EXAMPLE 1: Find orifice area and maximum pressure. A_p = 1; c = 0·7; S = 12; v_1 = 20; $v_2 = 0.05\,v_1$; W = 1,000; w = 50. Using Eq. 12,

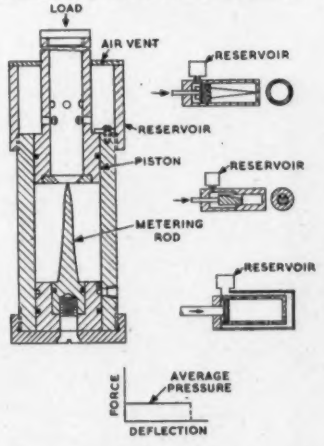
$$\ln \frac{20}{0.05(20)} = \frac{50(1)^3(12)}{3{,}456(0.7)^2A_o^2(1{,}000)}$$

$$A_o = 0.0109 \text{ sq. in.}$$

From Eq. 14,

$$P_{max} = \frac{50(1)^2(20)^2}{288(32.2)(0.7)^2(0.0109)^2} = 37{,}100 \text{ p.s.i.}$$

CONSTANT-PRESSURE SHOCK ABSORBERS



$$\int_0^{S(max)} FdS = \frac{1}{2} m(v_1^2 - v_2^2) \quad (15)$$

$$F = \frac{wA_p^3v_1^2}{288gc^2A_o^2} \quad (16)$$

$$v_f = \frac{vA_p}{A_o} \quad (17)$$

$$A_o = \left[\frac{wA_p^3(v_1^2 - 2aS}{288_o^2\, Wa}\right] \quad (18)$$

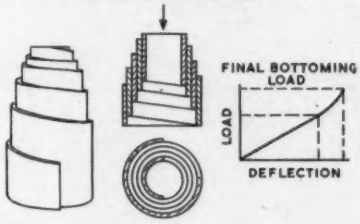
$$A_o = \left[\frac{wA_p^3(v_1^2 - 2aS)}{288_o^2W}\ \frac{1}{g + a}\right]^{\frac{1}{3}} \quad (19)$$

$$a = \frac{v_1^2}{2S_{max}} \quad (20)$$

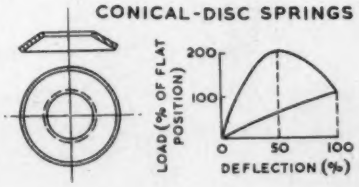
CODE

- A_p = Piston area, sq.in.
- A_o = Orifice area, sq.in.
- a = Acceleration of object, dv/dt, ft./sec.²
- c = Orifice discharge coefficient
- d = Piston diameter, in.
- E = Kinetic energy, ft.-lb.
- F = Force, lb.
- g = Acceleration of gravity, 32.2 ft./sec.²
- k = Spring rate, lb./in. of deflection
- m = Mass
- n = Ratio of specific heat at constant pressure to specific heat at constant volume.
- P = Pressure, p.s.i.
- p = Gas pressure, p.s.i.
- p_1 = Initial gas pressure, p.s.i.
- p_2 = Final gas pressure, p.s.i.
- S = Deflection or piston travel, in.
- S_1 = Internal length of cylinder, in.
- V = Gas volume, cu.ft.
- V_1 = Initial gas volume, cu.ft.
- V_2 = Final gas volume, cu.ft.
- v = Piston velocity, ft./sec.
- vf = Fluid velocity, ft./sec.
- v_1 = Initial piston velocity, ft./sec.
- v_2 = Final piston velocity, ft./sec.
- W = Weight of object, lb.
- w = Specific weight of fluid, lb./cu.ft.

VOLUTE SPRINGS

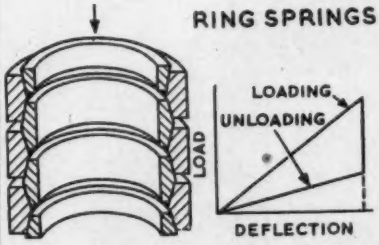


CONICAL-DISC SPRINGS



BELLEVILLE WASHERS

RING SPRINGS



Data by Lloyd M. Polentz

EMD 1655 for further information

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

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ALUMINIUM-NICKEL-IRON BRONZE

Engineering Materials and Design
DATA SHEET No. 25

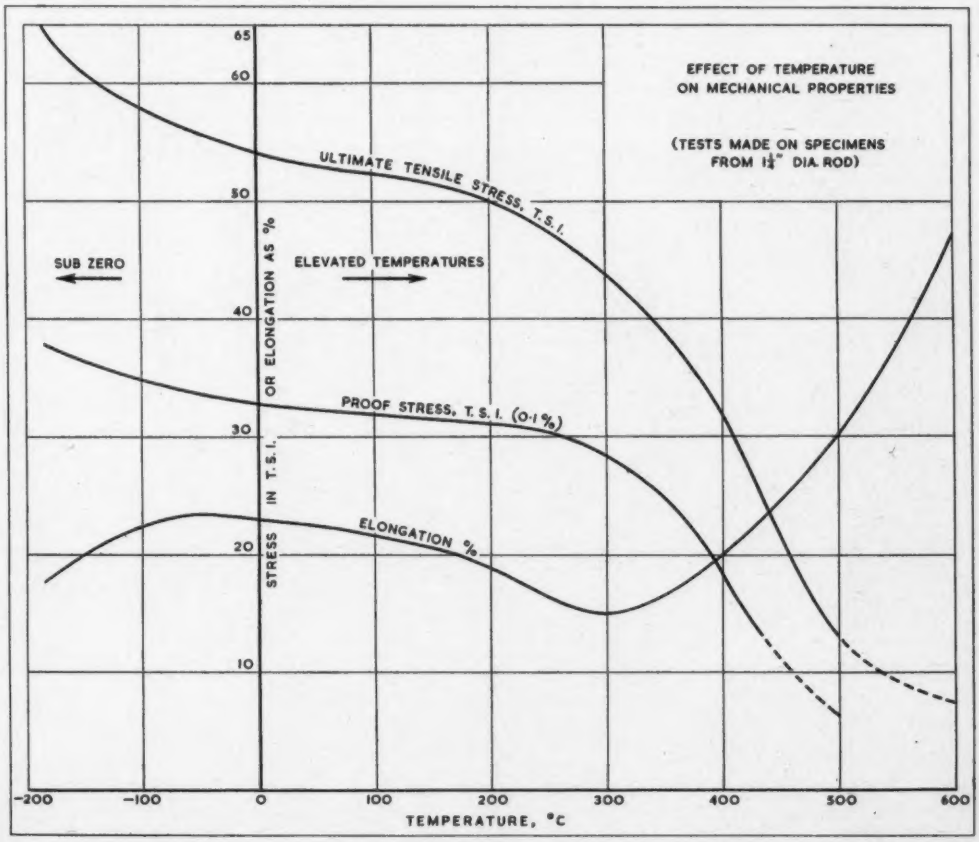
Composition (nominal)	80% copper, 10% aluminium 5% nickel, 5% iron.
Density	7·59 gm./cm.³; 0·274 lb./in.³
Melting range	1,060–1,075°C.
Specific heat	0·104 cal./gm./°C. approx.
Thermal conductivity	0·105 cal./cm.²/cm./sec./°C.
Thermal expansion coefficient	
20–100°C.	$15{\cdot}2 \times 10^{-6}$
20–200°C.	$16{\cdot}3 \times 10^{-6}$
20–300°C.	$17{\cdot}1 \times 10^{-6}$
20–400°C.	$17{\cdot}9 \times 10^{-6}$
20–500°C.	$18{\cdot}4 \times 10^{-6}$
Electrical conductivity (at 20°C.)	0·047 megmho-cm. or 8·2% I.A.C.S.
Specific resistivity (at 20°C.)	21·1 microhm-cm.
Brinell hardness range	179–255 kg./mm².
Izod impact value	10–20 ft. lb.
Torsional properties	
Shear stress at limit of proportionality	8·5–10·5 t.s.i.
Shear stress at permanent strain of 0·001 radians	12–22 t.s.i. (according to size of bar stock)
Modulus of rupture (max. shear stress)	35–40 t.s.i.
Modulus of rigidity	3,200 t.s.i. approx.
Total twist at fracture (4½ in. gauge length, 0·5 in. dia.)	300° approx.
Fatigue properties	
in air—20°C.	± 27·0 t.s.i. at 10^6 reversals
	± 22·0 t.s.i. at 10^7 reversals
	± 20·9 t.s.i. at 10^8 reversals
in air—300°C.	± 18·0 t.s.i. at 10^8 reversals
in air—400°C.	± 17·5 t.s.i. at 10^8 reversals
in salt spray—20°C.	± 26·0 t.s.i. at 10^6 reversals
	± 17·8 t.s.i. at 10^7 reversals
	± 10·8 t.s.i. at 10^8 reversals
Forms available	Rods, bars, simple sections, tubes, plates, sheets, forgings.

Tensile Properties

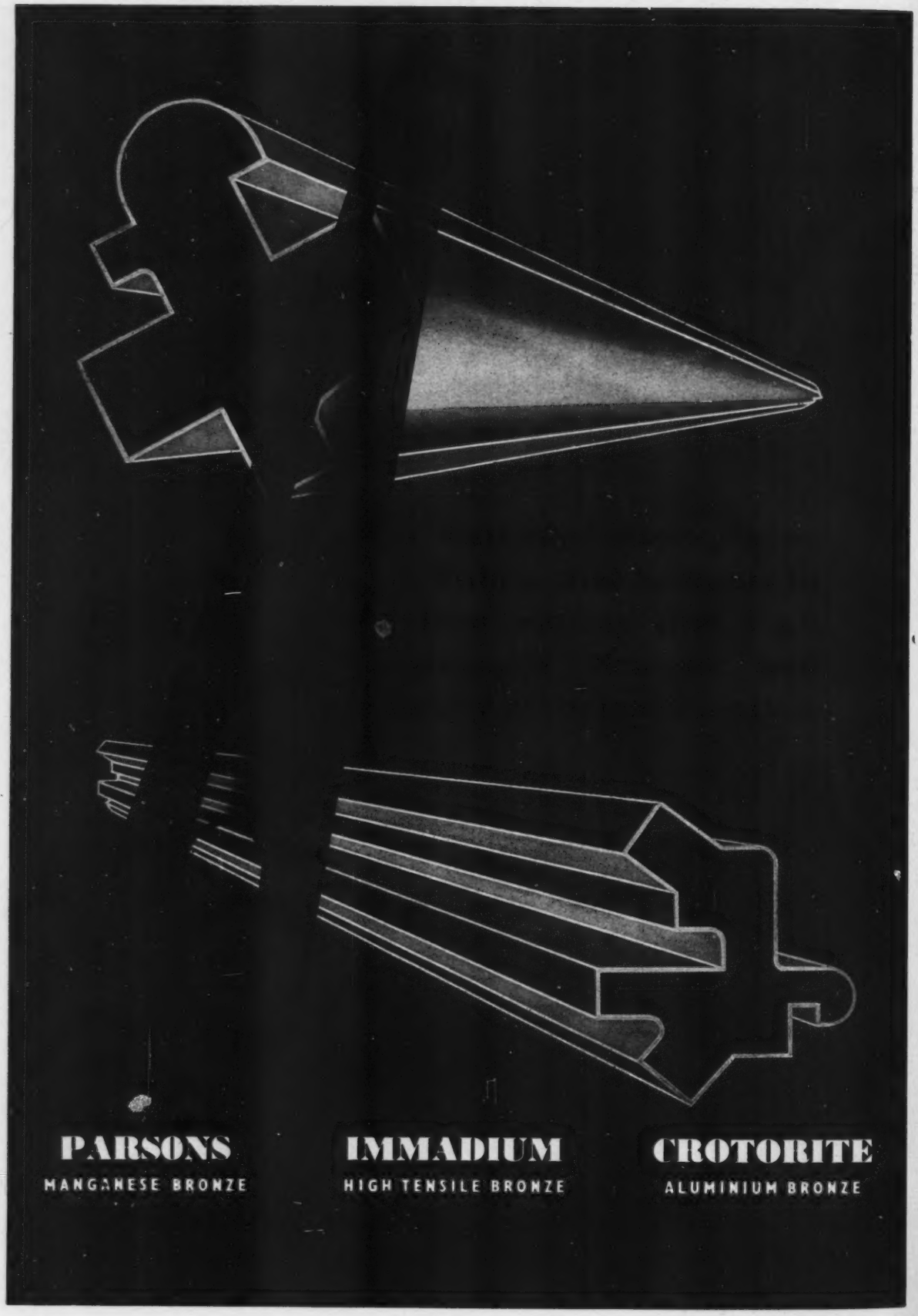
	Size (dia. or width across flats)	B.S. 2033 (min.)	Normal Range
U.T.S.	All sizes	45 t.s.i.	45–55 t.s.i.
0·1% Proof	Up to 3 in.	25 t.s.i.	25–35 t.s.i.
	3 in. to 5 in.	22 t.s.i.	22–28 t.s.i.
	Over 5 in.	20 t.s.i.	20–25 t.s.i.
Elongation ($4\sqrt{A}$)	All sizes	15%	15–25%
Modulus of elasticity	$17{\cdot}9 \times 10^6$ p.s.i. (8,000 t.s.i.)		

Creep Data

Temperature (°C.)	Stress (t.s.i.)	Time (hr.)	Total Creep Strain (%)
250	8	100	0·046
250	8	300	0·054
250	10	940	0·075
300	5·9	100	0·10
300	9·3	100	0·20
300	11·5	100	0·50
300	4·5	300	0·10
300	7·0	300	0·16
300	8·0	300	0·20
300	10·0	300	0·35
300	10·8	300	0·50
400	4·0	100	0·16
400	4·0	300	0·24
400	4·0	500	0·30
400	8·0	100	1·20
400	8·0	300	1·80



Data sheet by the Manganese Bronze & Brass Co. Ltd.


PARSONS
MANGANESE BRONZE
IMMADIUM
HIGH TENSILE BRONZE
CROTORITE
ALUMINIUM BRONZE

Is There No Future for the Inventor?

Sir,

You very pertinently ask in your August - September leading article: "When Are Patents Worthwhile?", and equally pertinently conclude that "Creative thinking must be actively encouraged . . . if we are to keep abreast of the technical advances in the U.S.A. and Russia".

But what, in fact, is being done to implement the facilitation of creative thought? Is it anything like enough? The Government, in conceiving the National Research Development Corporation, and lately by proposing to double its loan to £10 million, clearly appreciates the need for activity in one sense, but the N.R.D.C. was solely framed and evolved to exploit Ministry and allied developments and rarely interests itself in independent inventions, to the particular needs of which it is not in any case favourably constituted. There is a profound gap here, in which the only significant effort is being pioneered by the Institute of Patentees and Inventors in London. . . . Yet in this vast and vital field the I.P.I. subsists alone on voluntary memberships and receives no official or financial aids whatsoever.

How much is being lost in this gap, embracing as it does the whole field outside specific Ministry research establishments and universities? Only by a chain of flukes and after years of wasted frustration was Mr. C. S. Cockerell's Hovercraft seriously examined, and Prof. P. M. S. Blackett has admitted that it could well have been lost altogether. But what of the tens of thousands of other useful and profitable ideas and developments, some of which may be less spectacular but in mass are certainly of vaster economic significance? . . .

It is well recognised that specialists in one industry often see best how their particular knowledge can advantage another, while many outstanding inventions have originated from outside industry altogether. In all such cases (if they are to bear fruit) the inventor must personally initiate searches, protection, development and eventual lodging of the project with some suitable manufacturer on a basis of mutual advantage. In this, his available choice of action is rather pathetic.

In any important development, loss of foreign rights, markets and royalties are to be avoided—on grounds of national economy if for nothing else. He may accordingly get his agents to apply for world cover, at a cost of perhaps some thousands of pounds, and await the home outcome for two or three or more years from our overloaded Patents Office. As an alternative, if he is not rich or, as an inventor, he is faced with the capitalisation of several inventions, he may be obliged to dispense with foreign cover himself and then (on the basis of provisional protection only, affording very limited security, and with a bare twelve months in which to perfect and complete) endeavour to find a manufacturer who will agree terms on an unsecured idea and foot the bill of employing their own agents to prepare and lodge different *final* specifications in the various countries, all within the International Convention time-limits.

In practice, both these alternatives are usually so impossible that he contents himself with British cover only, thus losing to this country all foreign rights, markets and royalties automatically. Circumstances have compelled him to give the development free to foreigners, and the most he can hope for is a little from the pockets of his compatriots. And how attractive is this outcome to exporting manufacturers? Well may either ask if it was worth the bother! . . .

It is hardly surprising so many inventors get "browned off". Where is that encouragement that you and others demand?

While patent activity in some British concerns is admittedly often overdone, to the negligible long-term advantage of anyone, you have touched on a fundamental issue of the deepest significance to our prosperity, prestige and progress. . . .

J. R. C. Moore

Speciality Instruments,
Little Melton,

Poor British Publicity

Sir,

As an editor of Canada's leading metalworking magazine, I find that . . . each day my desk is flooded with news releases, new product announcements, new publicity catalogues, brochures and bulletins from many parts of the world. Many of them come from firms which really have far less to tell us than many British firms, which apparently don't think it worth the threepenny postage to tell Canadians what they have to offer, or what they are doing. Furthermore, those British releases we do receive are so often very badly compiled, badly typed on the inevitable foolscap sheets, and accompanied by feeble illustrations.

Modesty may be a virtue in some respects, but I suggest that it is no virtue on the part of people hoping to attract attention in one of the world's most fertile metalworking markets, and in a country where the fellow who shouts the loudest so often gets the business.

James A. Weller

Don Mills, Ont.,

We are publishing this letter not because our readers are primarily concerned with publicity, but because we feel they should read the views of a man who is in a good position to know how British publicity compares with that of other countries. We do suggest, however, that engineering designers should take more interest in these affairs than they have in the past. They could do much to meet this criticism by constructive comments on their publicity departments and in particular they could take a more active part in writing technical brochures. Most publicity officers would, we feel sure, welcome closer co-operation with technical staff.

New Books

Progress in Cryogenics. *Editor: K. Mendelssohn.* (*Heywood, 63s.*)

CRYOGENICS, or low-temperature technology, has developed rapidly in recent years under the stimulus of a wide variety of applications, particularly those associated with rocket propulsion and control systems.

It is a praiseworthy aim of this important publication to acquaint workers in one branch of the subject with the progress in others. This first volume of the series contains nine contributions by international authorities in their respective subjects, and the information is presented and critically reviewed in a manner which emphasises the salient features of the progress so far made and indicates the lines along which future efforts will be directed.

It is to the credit of the editor that these specialised topics with their individual mode of study have been brought together into an easily readable collection without loss of clarity or conciseness in detail, and this first volume suggests that the complete work will be recognised as an essential text-book for the student and a valuable reference book for the advanced worker in the deep-low-temperature field.

D. H. Tantam

Survey of Dielectric Materials. *By C. G. Garton.* (*Electrical Research Association, 15s.*)

This is a concentrated review mainly of developments since 1951 in the field of insulating materials. Among organic polymers are listed p.t.f.e., Terylene, nylon, silicone rubber, polystyrene, polyethylene and alkyd resins, with useful comments on their main characteristics. An interesting section refers to inorganic materials such as boron and silicon nitrides, mica and mica products, metal oxides and inorganic polymers. The last section summarises research on the mechanism of breakdown and the effect of impurities.

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WHAT'S NEW IN MATERIALS & COMPONENTS

Nickel-base Brazing Alloy

W.G. Nicrobraz is a nickel-base brazing alloy for joining steel surfaces with large clearances. It is claimed to make it possible to fabricate production pieces at a considerable cost saving. The method of application is to apply the paste formed from mixing Nicrobraz powder with the cement supplied on to the joint so as to fill the gap completely. Extra alloy must be added outside the joint to supply sufficient metal to fill the joint after melting. The joint must be maintained at brazing temperature for 30 min. or less according to the results desired. It is said to be suitable for use on parts of large cross-sectional area and for sheet metal assemblies where the sheet thickness is not less than $\frac{1}{16}$ in. Wall Colmonoy (Canada) Ltd.

EMD 1713 for further information

Plastics-covered Steel Tube

Burcol plastics-covered tubing and rod is available for electrical conduit, gas, water and steam installations and also for decorative purposes. Special slightly undersized tubes are supplied to give an exact outside diameter after application of the sheath, but formers and rolls for other standard-sized tubes need to be slightly oversize. Although close tube joints are not normally intended for bending, they can be bent satisfactorily within certain limits. The p.v.c. covering is claimed to resist abrasion and to be highly resistant to fumes of ammonia, hydrogen sulphide, sulphur dioxide, sulphuric acid, etc. LaBurn Ltd.

EMD 1714 for further information

Flexible Magnetic Strip

Koroseal flexible magnetic strips are flexible extrusions which contain a synthetic highly-magnetic powder. The extrusion is given a strong magnetic charge which is claimed to last indefinitely. The strips are available in standard extrusions of substantially rectangular form measuring 0·141 in. by $\frac{1}{8}$ in., 0·171 in. by $\frac{1}{8}$ in., 0·180 in. by $\frac{1}{8}$ in. and 0·250 in. by $\frac{1}{32}$ in. It is available in black only.

Koroseal magnetic strip was originally developed for insertion into a flexible gasket, where its flexibility enabled it to conform to irregularities of the mating members. Unlike iron-type magnets, it can be spot or shape magnetised as required. It can therefore be magnetised with a series of identical poles across the width, or these poles can alternate from side to side.

The largest use so far has been for refrigerator doors, but applications for dishwashers and electric clothes driers are now being tested by the manufacturers. It has been found useful for temporary fixing to cabinets and other parts on conveyor lines to prevent jarring and scratching, and for display work where signs must constantly be changed without leaving a mark. B.T.R. Industries Ltd.

EMD 1715 for further information

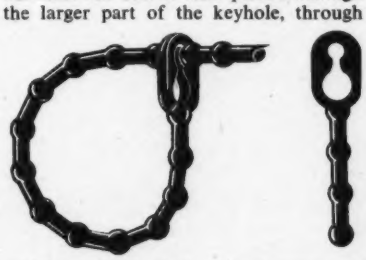
Pressure-sensitive Tape

Speedfix pipeline-identification pressure-sensitive tape enables appropriate labelling of pipelines to be carried out in a few seconds. The material is claimed to be completely waterproof and not to fade or break up by weathering. Each roll is 50 yards in length and can be obtained in various widths, generally from 1-3 in., but other widths can be supplied. Most of the colours specified in B.S. 381C can be matched. Industrial Tapes Ltd.

EMD 1716 for further information

Polyethylene Cable Strap

Polystrap is the name given to a new binding device suitable for the rapid bundling together and tying of cables, wires or threads. It consists of moulded polyethylene rod of about $\frac{1}{16}$ in. dia., at short intervals along the length of which are spherical enlargements. Each Polystrap terminates in a loop, the hole in which is of keyhole shape. The strap is simply looped around the cables to be tied and the end is then passed through the larger part of the keyhole, through



which the spherical enlargements can pass freely. When the desired degree of tightness has been reached, the nearest smaller-diameter portion of the strap is jerked into the smaller part of the keyhole, thus securing the cables. Polystrap is available in many colours, the stock shade being white. Hellermann Ltd.

EMD 1717 for further information

Heat-resistant Conveyor Belt

A new synthetic rubber conveyor belt constructed to handle hot and abrasive materials has been developed for use in the iron, steel, chemical, cement and gas industries. The belt, known as Star-hete, has a cover of synthetic rubber which will withstand temperatures up to 180 deg. C., and can be supplied with a carcase weight of duck and in ply ratings to suit all conditions and loads. Dunlop Rubber Co. Ltd. (Belting Division).

EMD 1718 for further information

Anti-tarnish Treatment for Silver

A simple electrolytic treatment known as Argalin is announced. The components to be treated are immersed in the solution for 1-2 min., then rinsed and dried. It is claimed that silver-plated articles treated in this way can be immersed for half an hour in a 2 per cent potassium sulphide solution without any appreciable change in appearance.

Argalin is claimed to be suitable not only for silver-plated cutlery and silverware, but also for electrical contacts, where its use prevents tarnish before assembly. It is said that the solderability or contact resistance of components so treated is unaffected. Roto-Finish Ltd.

EMD 1719 for further information

Conducting Plastics

Abbey 100, a vinyl compound, is claimed to be so highly conducting that it can be used in place of copper conductors in such applications as car ignition cables. Possible applications include safety equipment of many types, hospital operating-room equipment, impregnated paper for electronic recording instruments, gasketing and tubing, aircraft de-icing equipment, door-opening devices, anti-static devices, encapsulation devices and high-voltage conductor shielding. It is also said to be suitable for shielding in many applications where copper braiding would ordinarily be used. Croxton & Garry Ltd.

EMD 1720 for further information

Inert Thermoplastics

A new chemically-inert thermoplastics material, a chlorinated polyether derived from pentaerythritol, is claimed by the manufacturers to possess an unusual combination of properties for a thermoplastics, including excellent mechanical strength, high temperature resistance and good dimensional stability.

Known as K.51, it is stated to be inert to almost all alkalis, solvents, chlorides and inorganic acids. It is therefore considered to be suitable for the chemical industry for such applications as bearings, valve seats, sealing gaskets, washers, impellers and other parts operating under corrosive conditions. It is a comparatively rigid material, having a tensile strength of 6,000 p.s.i. and a Rockwell hardness of 100. It is claimed to have a high resistance to deformation under load and a very low cold-flow tendency compared with fluorocarbons, with good abrasive resistance. It can be subjected to operating temperatures in the range 120-130 deg. C. in an oxidising atmosphere.

It is available in a wide range of extruded shapes for machining on conventional metalworking equipment. Polypenco Ltd.

EMD 1721 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Clad Steel Plate

Colclad is the name given to a range of steel plates composed of two or more dissimilar metals bonded together to form a slab. They are mainly used in the fabrication of pressure vessels, fractionating columns, etc., in the chemical, food and process industries, where a resistant lining is required. The backing steel is normally of boiler quality, manufactured in accordance with the requirements of B.S. 14-1942 or B.S. 1501-151-154-157. A wide range of cladding materials can now be successfully bonded. These include 14 per cent Cr steel, 13 per cent Cr/Al steel, 18/8 stainless steel, 18/8 Ti, 18/8 Cb, 18/10/2 Cb, 18/10/2 Ti, "AT" nickel, "L" nickel and Monel.

In the fabrication of vessels from Colclad, the plates are first aligned and tack welded. The mild-steel side is then welded first. After completion of the mild-steel weld, the clad side is prepared by chipping back to clean metal and thereafter welded with the appropriate alloy electrode. Colvilles Ltd.

EMD 1722 for further information

Micro-particle Filter

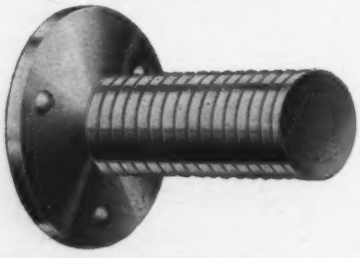
The Micron filter has been produced to meet the demand for highly-efficient filtration of fluid in precision hydraulic equipment. Two models are available for operation in systems with line pressures of up to 2,000 p.s.i., one for direct line filtration and the other for integral mounting on the manufacturer's electro-hydraulic servo valve.

The filter element can be conveniently serviced or replaced by removing a circlip and end cap at the base of the filter body. The Micron filter, which is claimed to collect particles of 5 microns and over, weighs 21 lb. without the servo valve. Sperry Gyroscope Co. Ltd.

EMD 1723 for further information

Weld Bolts

These bolts have been specially developed for projection welding and are said to have many applications in the



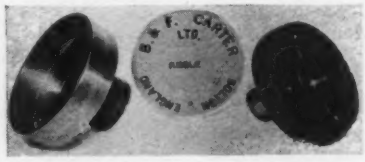
sphere of sheet metal working and can be used for all kinds of assemblies. They are made from 28-32 t.s.i. mild steel and stress-relieved after manufacture to remove the cold forging stresses. They are supplied in natural finish and in all the common threads. It is claimed that the speed with which these bolts can be fitted enables production costs to be greatly reduced in the manufacture of such items as door panels, bulkheads, dash panels, brackets, etc., on domestic appliances, motor cars, switchgear and a wide range of machinery. Thos. Haddon & Stokes Ltd.

EMD 1724 for further information

Centrifugal Clutches

The Ribble automatic spring-controlled centrifugal clutches are claimed to enable the designer to employ squirrel-cage-type motors, with economical direct-on starting with the associated inexpensive switchgear. Any form of overload is said to cause the clutch shoes to slip and thus provide a safety link.

The clutch consists of a driving member, clutch casing, the loose weights (of which there are four) and the cover plate. The fixed driving member has four arms which restrain the weights during rotation, these being retained axially by the casing and the aluminium cover. A flat steel spring passes freely through



each weight with the ends fitting into slots at the extremity of the four arms. An adjusting screw, tapped through the inner face of each weight, exerts a pressure against the spring to "hold off" the weight, the screw being fixed by a locknut. The casings are made of high-tensile, close-grained, cast iron, and are bushed with self-lubricating, oil-impregnated, phosphor-bronze sleeves. The cover plate is of aluminium.

The clutch springs are normally adjusted by the manufacturers to take up load at approximately 75 per cent of full speed. Sizes are available for 1 h.p. at 1,400 r.p.m. to 9 h.p. at 1,400 r.p.m. B. & F. Carter & Co. Ltd.

EMD 1725 for further information

Gaugeless Multi-stage Regulator

A multi-stage gaugeless regulator for use with industrial gas cylinders, designed to deliver a constant working pressure regardless of incoming pressure and which has a minimum variation from flow to no-flow, is now manufactured in this country by agreement with the Harris Calorific Co., of Cleveland, U.S.A.

Known as the 77N regulator, the apparatus has a cylinder pressure gauge and a working pressure indicator with pressures impressed into the bonnet instead of the normal pressure gauge. The pressure required is selected by an adjusting screw, the thimble of which prevents dirt, etc., from lodging on the threads. Once the regulator is set, the delivery pressure is said to remain constant from full to empty cylinder.

It is claimed that, with this regulator, improper procedure is eliminated and full cylinder pressure can be turned on with the adjusting screw in any position without danger. It is claimed that the regulator requires virtually no attention. British Industrial Gases Ltd.

EMD 1726 for further information

Small Lubricating Pump

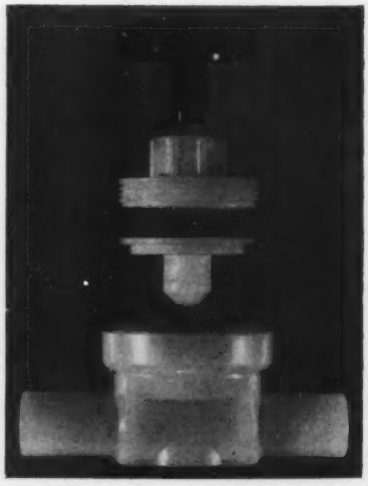
The Pilgrim PW-313, a small mechanical lubricating pump, has been designed to run at low speeds; at 200 r.p.m. it takes 7½ hr. to deliver 1 c.c. of oil from each of the two delivery pipes. Both deliveries are fitted with separate plungers, and at 200 r.p.m. each plunger operates once every ½ hr., displacing 0·066 c.c. of oil, which is delivered during a 15-min. period. A 6,000:1 gear reduction is fitted. Although intended for use at low speeds, the pump can operate efficiently up to 3,000 r.p.m., deliveries and times being *pro rata*. Pilgrims Way Motor Co. Ltd.

EMD 1727 for further information

Plastics Valve

The accompanying photograph shows the construction of a valve in high-density polyethylene which is claimed to be leakproof, there being no mechanical shafts or stuffing gland. The conical plug is moulded integrally with a diaphragm which maintains a valve in the open position when the operating screw, bearing against its upper surface when the valve is to be shut, is released. The rim of the diaphragm acts as a seal, being trapped between the upper portion of the valve through which the operating screw passes and a step in the body of the valve. Turning the operating screw knob clockwise causes the screw-end to bear against the top of the diaphragm and so cause the plug to seat. The valve, although intended for on-off duty, can also be used for partial throttling.

It is at present offered in ¼ in. and



1 in. dia. sizes which can be threaded either internally or externally to order, or left plain. Alternatively, flanged ends can be supplied. The valve is suitable for pressures of around 70 p.s.i. and for temperatures of up to 60 deg. C. K.W. Chemicals Ltd.

EMD 1728 for further information

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THE ROSAN PRESS NUT

Pat. App.
No. 19826/57

The Rosan Press Nut provides a quick and secure deep tapped hole in metal sheet or plate. It is cheaper to buy than other methods and much quicker, easier and cheaper to fix. Improve your production and your product with the Rosan Press Nut. Write today for samples.

Among the many firms which are household words using Rosan Press Nuts are:

Keith Blackman Ltd., Chubb & Sons Lock & Safe Co. Ltd., Igranic Electric Co. Ltd., Pye Telecommunications Ltd., Vickers-Armstrong (Engineers) Ltd., Dynatron Radio Ltd., Claude Lyons Ltd., Elliott Brothers (London) Ltd., Electric & Musical Industries Ltd., Marconi's Wireless Telegraph Co. Ltd., Standard Telephones and Cables Ltd., Thorn Electrical Industries Ltd., Westinghouse Brake & Signal Co. Ltd., The Plessey Co. Ltd., The United Kingdom Atomic Energy Authority and many others.

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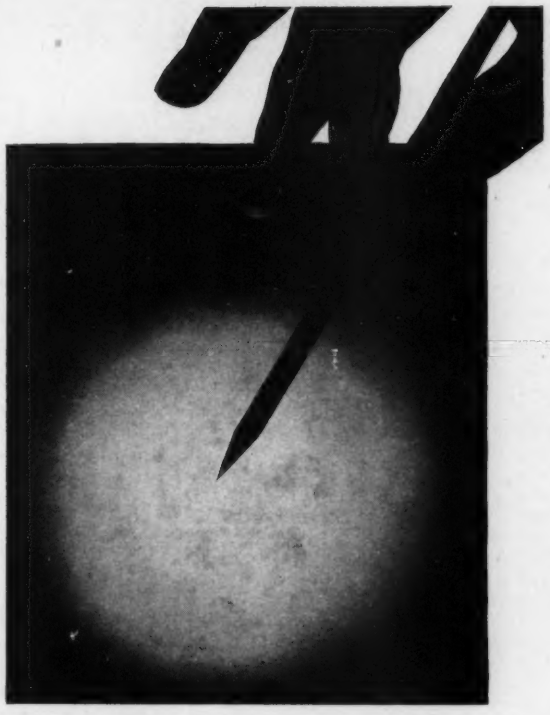

"probably the most potent instrument in the world"

For it gives most of man's thoughts and aspirations their first tangible form.

Consider a pencil, What an elegant little shaft it is! Basically simple, yet how indispensable to the most complex design! Notice how comfortably it sits in the fingers; for the polished cedar hexagon of a well-bred pencil with its many coats of gleaming lacquer, never forces itself upon one's consciousness, but, like a good servant, unobtrusively awaits one's bidding. Its smooth dense lead will give perfect reproduction of the finest lines, which nevertheless can easily be erased. The perfect point good humouredly stands heavy pressure and does not break, even when dropped. Pick up any degree from 6H to 2B (easily recognised by the coloured ends), they are true and never vary.

How fortunate is the draughtsman who finds all these attributes embodied in one pencil!

Perhaps that is why Rolls-Royce exclusively specify Koh-i-noor in their drawing offices.

KOH-I-NOOR

TO L. & C. HARDTMUTH (GREAT BRITAIN) LIMITED
KOH-I-NOOR FACTORY, CHARD, SOMERSET

Please send free samples of Koh-i-noor Draughtsman pencils for testing.

NAME OF COMPANY .....

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Compact Battery

A smaller lighter cell which gives a higher performance to a new range of Plante batteries has been developed. The outstanding feature of these new cells is said to be a saving in space of up to 50 per cent compared with cells made to B.S. 440, with a reduction in weight.

The positive plates, of improved design, are worked in conjunction with negative plates of the pasted type. Separators are of Porvic 2, a development of the microporous plastics which is claimed to be virtually indestructible in service.

The new cells have been specially designed for stand-by duties entailing discharge rates between the 3-hr. rate and the very high rates demanded for switch-closing purposes. They are stated to be ideal for trickle charging operation. Duties for which they are said to be suitable include switch-tripping, telephones, supervisory and signalling and also stand-by duty.

Fourteen different sizes of cells are available in the new range, with capacities ranging from 15-400 amp. hr. at the 10-hr. rate of discharge. For duties requiring extra high currents, the cells can be supplied with copper inserts in the pillars to increase conductivity. Chloride Batteries Ltd.

EMD 1729 for further information

Electronic Flowmeters

The Rochar range of electronic flowmeters for the measurement of instantaneous rate and integrated volume of flow of liquids is now being marketed in this country.

These flowmeters use volumetric transducers of the magnetic-induction type and consist of a cylindrical body, through which the liquid passes, and a free rotor with helicoidal blades whose speed of rotation is proportional to the rate of flow. The alternating signal output from the transducer has a frequency in cycles per second equal to the revolutions per second of the rotor. The signal from the transducer is fed into the instrument proper, which consists essentially of a frequency meter with a pulse-shaping circuit and an output meter calibrated in terms of instantaneous rate of flow. An auxiliary circuit provides an output pulse for every complete unit of volume which is fed to a mechanical counter to indicate the total volume of flow at any time.

The transducers are machined from heavy-duty alloy and are claimed to withstand corrosion from nitric acid, liquid oxygen, jet and rocket motor fuels. Installation is said to be simple.

The range of flow rate covered is from about 4 to 22,000 gal./hr., and calibration can be effected in any units required. Metrix Instruments Ltd.

EMD 1730 for further information

Edge-lit Indicator

A new digital indicator is of the edge-illuminated, superimposed engraved character type. It consists of a flange-mounted rectangular body which contains the engraved characters on clear acrylic plates and is provided with a magazine for six 1-watt lamps at each end. Individual engraved characters are illuminated by selecting and energising the circuit to the appropriate lamp or lamps. The component may be mounted by two screws on the front or rear of the equipment. Provision for twelve separate characters is made. Normally the integers 0-9 are used with the decimal point in the left-hand position (normally lit by two lamps). In addition to these, "plus" and "minus" may be provided, or a decimal point in the right-hand position. Characters are $\frac{1}{4}$ in. high and $\frac{7}{16}$ in. wide, and with the exception of the decimal point are displayed centrally in the window of the indicator. The separate engraved acrylic plates are spring-loaded together to prevent the ingress of dust between characters.

The edge-lit indicator can be supplied as a separate unit or, complete with ancillary relay equipment, as a complete read-out system. A coloured or neutral filter can be supplied if required. Thorn Electrical Industries Ltd.

EMD 1731 for further information

Gauging Balls

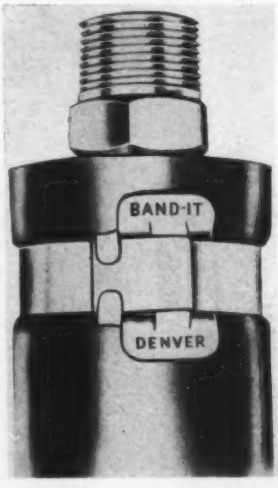
Master gauging balls, available in sizes from 3/64 to 1 in. in dia. in 1/64-in. increments are now available in this country. Made from chrome alloy steel and hardened to 63-65 Rockwell C, tolerances are held to ±0·000010 in. on diameter and 0·000010 in. on sphericity. Surface finish is 1 micro-inch. They are available in sets or singly, for use in standards, metrology and inspection departments. Insley Industrial Supply Co. Ltd.

EMD 1732 for further information

Pipe Clamping System

The Band-It stainless-steel pipe clamping system is said to provide a number of advantages over the conventional hose couplings used in mines, where the water is highly corrosive owing to acidity.

Unlike conventional hose clips which are made to fit a particular size of hose, the Band-It system employs a steel band which is applied by a hand-operated tool. It is said to be particularly useful for carrying out on-the-spot repairs to leaking water pipes at the pit bottom,



where a number of different pipe diameters are sometimes encountered. It is only necessary to put a piece of rubber belting over the hole and secure it with a Band-It clamp. The system can also be used for pipe suspension, both underground and on the surface. The system would appear to have considerable possibilities in the general engineering field. G. E. Simm Engineering Ltd.

EMD 1733 for further information

Precision Limit Switch

A limit switch for which it is claimed that a fine adjustment of the roller initial position over a full $\frac{1}{4}$ in. is possible after the switch has been mounted and wired is announced. With this feature it is said that it is a simple matter to locate the roller in the proper relation to the cam track. Roller direction can be changed through 90 deg. without the use of tools, so that the roller operating direction is perpendicular to the bottom of the box.

The switches contain a precision snap switch mechanism designed to withstand the kind of conditions encountered in machine tool control. Contacts are single-pole, double-throw with isolated normally-open and normally-closed circuits. The enclosure of the switch consists of a diecast box with a conduit entrance at one end and drilled so that it may be mounted on either side of the back. The snap switch, roller plunger and over-travel mechanism are attached to the cover which is symmetrical with the box, thus giving a total of six different mounting arrangements with one device.

The switch is designated class 9007, type AW-36. A similar switch but without the plug-in feature, designated type AW-32, is also available. Square D Ltd.

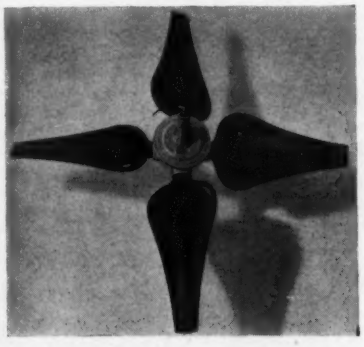
EMD 1734 for further information

Hollow Plastics Fans

A standard range of plastics fans, ranging from 6-14 ft. in dia., is to be manufactured in the U.K. under the trade name Marex, under licence from the Hudson Engineering Corp., of Houston, U.S.A.

The fans, which are four-bladed, can be provided with two types of hub—either an auto-variable one, in which a pneumatically-activated diaphragm alters the angle of pitch while the fan is in motion, or the adjustable-pitch hub which requires that the fan be stopped while a simple manual alteration of pitch is carried out. On both hubs the angle of pitch may be varied between −15 and 30 deg.

The blades, which are hollow, are made of woven glass cloth and pigmented epoxy resin, laminated as a one-



piece moulding. These materials make a self-coloured blade which is corrosion- and heat-resistant, while the method of construction gives the blades a smooth surface, high strength and low weight. They are claimed not to shatter or fragment and, being hollow, are extremely light. Fan blades of the same size are readily interchangeable.

The blades are claimed to be suitable for hot, dry conditions, as encountered in desert areas, and also for moving hot, moist air from water cooling towers. They can also be used in corrosive-laden air from chemical process vats. Marston Excelsior Ltd.

EMD 1735 for further information

Electrolytic Capacitors

Long shelf life and a working life of the order of ten years are claimed for a new type of electrolytic capacitor. The capacitors are known as Hyperlytic and are available in many capacities between ½ and 12,000 mF.

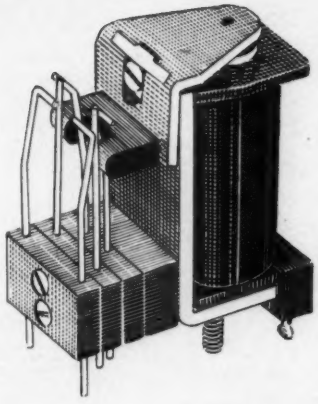
The use of a high-purity etched foil anode material, combined with a unique manufacturing technique, is said to provide a stable capacitor having low leakage and high insulation resistance. Two types are available, the 1,000 and 11,000 series. The 1,000 series has a temperature range of −30 to +85 deg. C. The 11,000 series has a working temperature range of −20 to +50 deg. C., with a somewhat higher leakage current. The standard capacitance tolerance is −20 to +50 per cent, but closer limits can be worked on request. Plessey Co. Ltd.

EMD 1736 for further information

Miniature Relay

A new relay is announced which is intended for use in circuits requiring a small two-changeover relay with low capacitance between springs and between springs and frame. The conventional flat springs have been replaced by wire springs mounted in moulded blocks.

Dimensions and fixing arrangements are for the standard miniature G.P. relay,



i.e., 1·54 × 1·09 × 0·48 in. An acrylic cover can be supplied for the spring set. The relay is suitable for operation in ambient temperatures in the −40 to +85 deg. C. range. Ericsson Telephones Ltd.

EMD 1737 for further information

Shaft Seal

Latest versions of the Crane type 1A and 2 mechanical shaft seals now incorporate a number of new refinements. The normal temperature range for these types is from −40 deg. C. to +80 deg. C., provided that the liquid being pumped does not affect the rubber components of the seals at these temperatures.

If, however, these seals are supplied with extended surface seats—a new development—they can be used when liquids are being handled near their boiling points, up to a maximum of 120 deg. C. Types 1A and 2 seals are supplied to fit shafts from ¼ in. to 4 in. in dia. They can be used at running speeds up to 3,000 r.p.m., or at higher speeds if special cooling arrangements are installed. Crane Packing Ltd.

EMD 1738 for further information

. . . at the Engineering Industries Association Display (London, October 20-22)

Submersible Pumps

D.A.G. submersible triple-purpose pumps will be shown, which mix, pump and circulate in one operation. They are said to be specially designed for use in all forms of laboratory mixing, and the processing of a variety of fluids in temperatures up to 120 deg. C. They can be left functioning, it is said, for long periods with only a minimum of supervision. D. A. Gunn (Engineering) Ltd.

EMD 1739 for further information

Die Feeds

The die feeds being shown by the Carter Screw & Engineering Co. are said to have been demonstrated in production at a continuous speed of over 400 strokes per minute on all types of material and press tools. They have virtually three moving parts and no functional springs.

EMD 1740 for further information

Dial Gauges

A new range of dial gauges will be shown by A. Capp & Son Ltd. Known as the Repeta and R.A. Repeta types, they are said to incorporate an entirely new design of lever fulcrum mechanism. The lever is pivoted between two precision ball race bearings; by this method, the lever actuates on a movable contact point, resulting in a frictionless movement. The worm spiral is set in jewelled bearings.

EMD 1741 for further information

Gold Alloy Plating

Introduced by Harris Plating Works Ltd., as sole concessionaires, is the new Thermocompact gold alloy plating process, which is claimed to give maximum hardness (400-450 deg. Vickers), great resistance to corrosion, minimum porosity, and at competitive cost. Makers recommend it for a wide variety of industrial applications, including contacts, printed circuits, transistors, etc.

EMD 1742 for further information

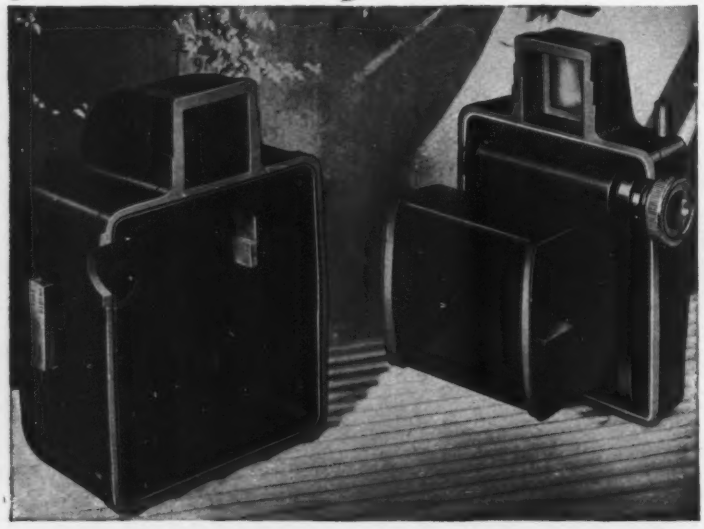
Ball-string Transmission

Visomag ball strings are a new motion and transmission element suitable for instruments and other precision apparatus. They are made from a tough, pliable plastics material (or from steel if required) into which balls are moulded at regular intervals. The string, when mounted on special small pulleys fitted with semi-spherical sockets, operates as a cog-wheel and chain, but because of its flexibility it can be guided in any direction. Standard diameters of string are from 0·5 mm. Inglis Knibb & Co.

EMD 1743 for further information

EMD 1660 for further information

Focus on economy



The rapid expansion of the photographic market has been accompanied by an ever increasing demand for a low-cost camera capable of taking photographs usually associated with more expensive models.

To meet this demand the Vista 12 was designed. It is another excellent example of how much can be produced for how little, when designer and plastic moulder work closely together.

The Vista 12 incorporates an eye-level viewfinder and precision optically ground glass lens system. It is synchronised for flash, takes a standard 120 film and produces excellent colour shots in bright sunlight. It retails at about £1.1.0d.

Whether you wish to sell to mass markets at budget prices or to more exclusive markets —we have the plant, experience and technical resources to meet your needs.

Six high impact, camera black, polystyrene mouldings and three chromium plated die castings are incorporated in the camera which when complete separates into two sections for loading and unloading. Our subsidiary, the British Optical Lens Co., designed and supplied the lens and viewfinder systems—incorporating optically ground glass lenses. The complete production from tools to assembly and packaging was handled by us.

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News of Industry

Reformulated grades of **Shell** Dromus soluble cutting oils now contain an improved coupling agent to facilitate the formation of a stable emulsion when the oil is mixed with cold water; the result is that the oils no longer possess the "antiseptic" odour usually associated with soluble cutting oils. In addition, the absence of the conventional phenolic coupling agent reduces the tendency of the emulsion to cause irritation of sensitive skins.

The 1960 **Design Engineering Show** is to be held at the Coliseum exhibition building in New York from May 23-26. Over 17,000 visitors attended the 1959 show during its four-day run, when the A.S.M.E. held its annual design conference.

A motor car division has been formed by **Bristol Siddeley Engines Ltd,** to coordinate the design, manufacture and marketing of the Armstrong Siddeley Star Sapphire **car.**

English Electric Co. have recently developed two types of automatic slow-down equipment, one mainly mechanical and the other electronic, for counting the turns on reversing cold strip mill reels during coiling and uncoiling. The equipment automatically determines the latest safe point to slow-down the mill for reversing. Although both types were originally designed for the steel industry, they can be applied to any industrial process where material is coiled on a reel.

The maximum turns count is about 1,600, but by changing the input gear ratio the equipment will count other than complete turns. A circular rheostat gives an electrical output, changing steadily during each fifty turns wound on or off the reel. The rheostat output is disconnected by a geared limit switch after the first fifty turns when coiling, so that it is only operative again during the last fifty turns when uncoiling.

Lawes Rabjohns Ltd. are to hold a series of six exhibitions of drawing-office equipment and materials at provincial centres during the coming months. The show will be in Newcastle from November 2-5 and in Sheffield from November 24-27. Later it is to move to Liverpool, Wolverhampton, Bristol and Ealing.

The annual report for 1958 of **Rubber Technical Developments Ltd.** (an associate of the Natural Rubber Development Board) states that special attention was given during the year to improving processing and manufacturing methods of certain natural rubber products. For example, with graft polymer rubbers, in which natural rubber is combined with synthetic materials to make hard moulding compositions, etc., work has been directed to producing material which can be handled in the mixing plant without pre-conditioning. Trials carried out indicate that this can be best achieved with rubber modified from fresh latex on the plantation.

Further work was undertaken with the British Rubber Producers' Research Association in connection with anti-crystallising rubbers designed to prevent natural rubber from becoming brittle and unusable at low temperatures.

A new lead brick for use in shielding personnel against gamma, beta and alpha rays has been produced by a special "pressure moulding" technique by **British Lead Mills Ltd.** The company claims to be the first in the field with lead bricks produced by this process, to ensure the greatest density and freedom from porosity and inclusions within the fine limits permissible by the U.K.A.E.A.

The shield and £10 10s. cash prize in the **A.S.E.E.** Highfield Shield Competition has this year been won by Mr. D. H. Taylor for his paper on "The British Patent System". He has won also on five previous occasions.

A new division concerned with domestic electrical appliances has been set up by the **British Electrical and Allied Manufacturers' Association.**

The third olefin plant of **I.C.I. Ltd.** has recently been completed and successfully brought into operation at Wilton in North Yorkshire. About 90 per cent of the ethylene made there and at the company's adjacent plants is piped to the neighbouring plants of I.C.I. Plastics Division for manufacturing polyethylene. Other products from the plant include propylene.

The **Society of Glass Technology** has announced that its journal will be published in two parts, starting in February, 1960. These will be known as *Glass Technology* and *Physics and Chemistry of Glasses.*

Acme Conveyors Ltd. have transferred their detail design, buying and accounts departments to 58-62 Seaward Street, Glasgow, S.1. Technical sales and project departments continue at 1 Bradford Street, Walsall.

Donald Ross & Partners Ltd., who manufacture "Twinner" positioners for hand and automatic welding, have been acquired by Murex Welding Processes Ltd.

International Synthetic Rubber Co. Ltd. announces that work has started on a new plant to produce general-purpose synthetic rubber latex.

Permindex, a permanent industrial exhibition of international scope, opens in Rome next year. Backed by private capital, it is intended to form a permanent show where visitors may compare the products of many countries. Exhibits will be arranged by industry and product category rather than on a national basis, and will be changed periodically in sequence. Up to 3,000 exhibitors may be accommodated there, one-third of whom have already booked space. The exhibition will open in January 1960.

British agents for the exhibition are Industrial & Trade Fairs Ltd.

London office of **British Industrial Plastics Ltd.** has now been moved to Haymarket House, 28 Haymarket, S.W.1.

View of a pair of oil heaters and steam heaters, soaker lines and fractionation equipment at the I.C.I. olefin plant at Wilton, Yorks. (See story this page.)

At the Sheffield works of **Steel, Peech & Tozer,** a system has been evolved whereby a sample may be taken from the furnace and the analysis made available to the melting shop within ten minutes. This is an important step, as the furnace cannot be tapped until the analysis is satisfactory.

After the sample has been drawn from the furnace it is sent to the laboratory by pneumatic tube and analysed for trace elements by means of a direct-reading spectrometer. Because of the absorption by the atmosphere of the short wavelength radiation associated with carbon, sulphur and phosphorus, the instrument has been further developed to examine the spectrum under vacuum, thus enabling all the required constituents to be determined. By referring instrument recorder readings to the appropriate graphs obtained from standard steel samples, the percentage content of each element in the sample may be determined.

Details of construction of modern marine signalling equipment were shown recently during a Press visit to the Crawley works of **Stone-Chance Ltd.,** who claim to have built some 40 per cent of the world's lighthouses. Although the outward appearance of lighthouses follows rather traditional lines, most of the larger ones (such as that for Dwarka in India) are nevertheless produced individually for specific environments. One interesting development is the growing use of Perspex lenses, which provide extreme accuracy and high transmission, as well as economy. Another trend is the use of Xenon discharge lamps which result in a smaller lantern than in the past but with a similar light output.

EMD 1661 for further information

"This is the good brand, Excalibur, or Cut Steel, and well shall it serve you"

IN FABLE . . . *When King Pellinore shattered King Arthur's sword in combat, the problem of a more worthy weapon was solved by Merlin. . . . "Follow me, and I will bring you where ye shall get you a sword, the wonder of the world".*

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Greases, oils, soluble oils, water, acids and many loathsome chemical process liquors—even sludges—they are all lubricants to 'ORKOT.'

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EMD 1662 for further information